Introduction
to
Computer Vision

Lecturers:

- prof. Ender Konukoglu
- prof. Luc Van Gool
- prof. Fisher Yu

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The course comes with a **course text** that covers most – but not all ! – material.
Slide decks for all lectures will be made available and are the actual reference for study.

Computer Vision

We got questions about which course to take

Computer Vision (D-INFK), or
Image Analysis and Computer vision (this course)

IN ANY CASE, DO NOT TAKE BOTH !

If you took the introductory course on CV at D-INFK, then best take *Computer Vision*

If you did not take that course, then best take *Image Analysis and Computer Vision*

This introductory lecture:

1. **human perception**
2. **applications**
3. **light**

This introductory lecture:

1. human perception
2. applications
3. light

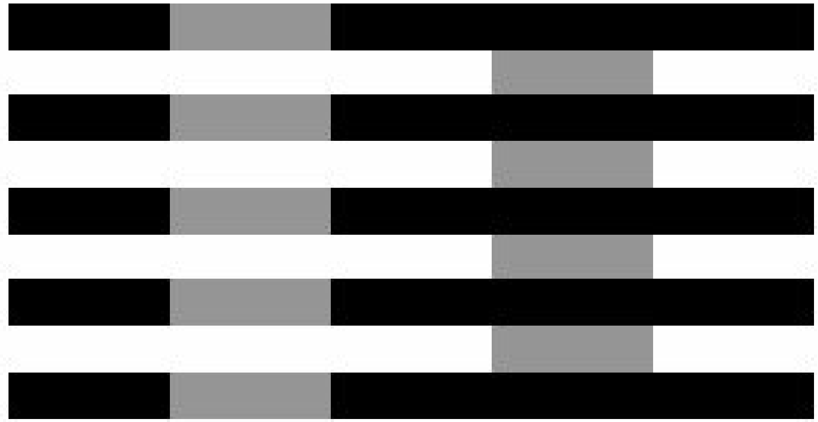
Vision is important

- half our brain is devoted to it
- developed multiple times during evolution
- it is non-contact
- it can be implemented with high resolution
- works with ambient E-M waves
- yields colour, texture, depth, motion, shape

The central take-home message:

For people vision is the most important sense, for good reason

The perception of intensity



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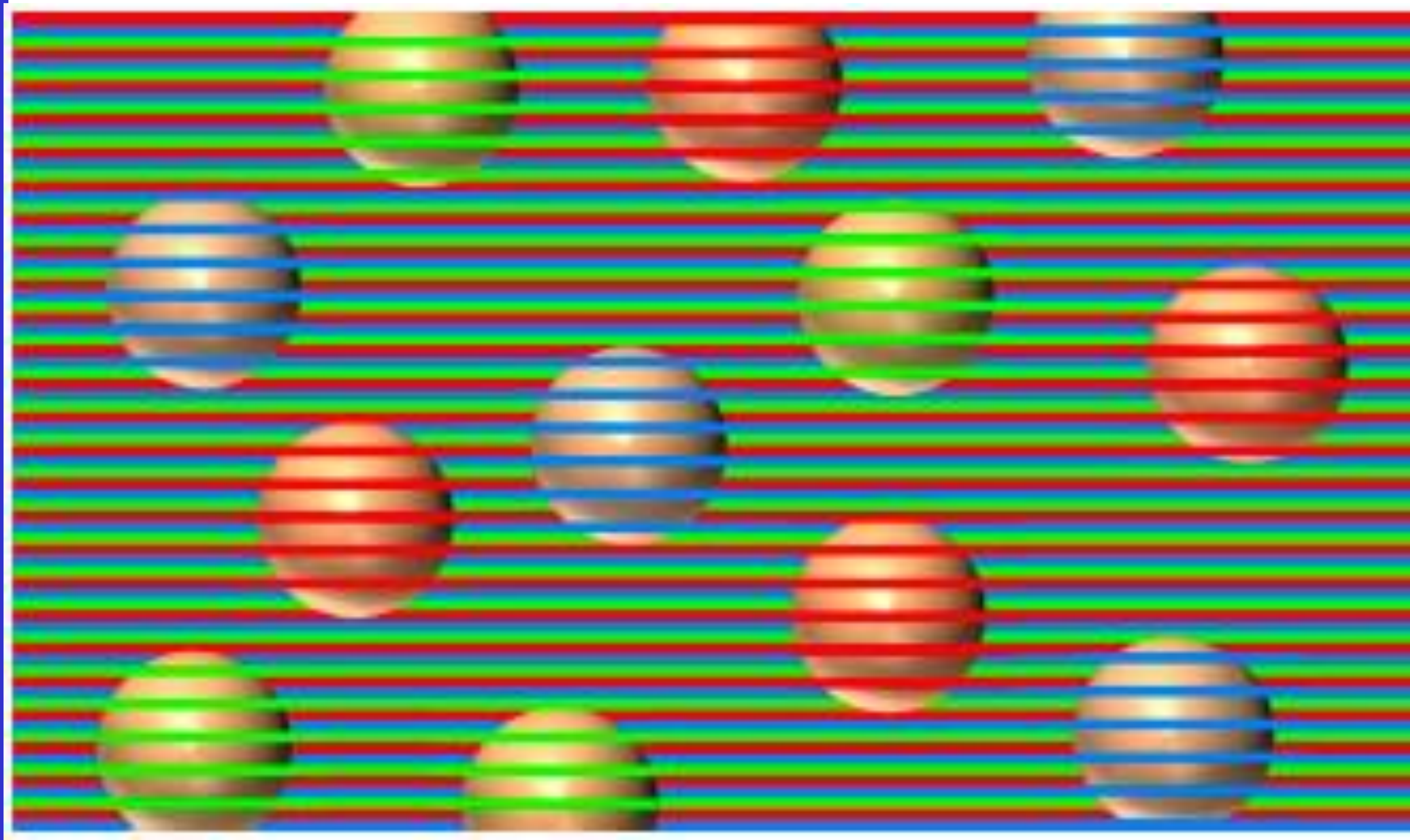
The perception of color



The balls all have the same color…

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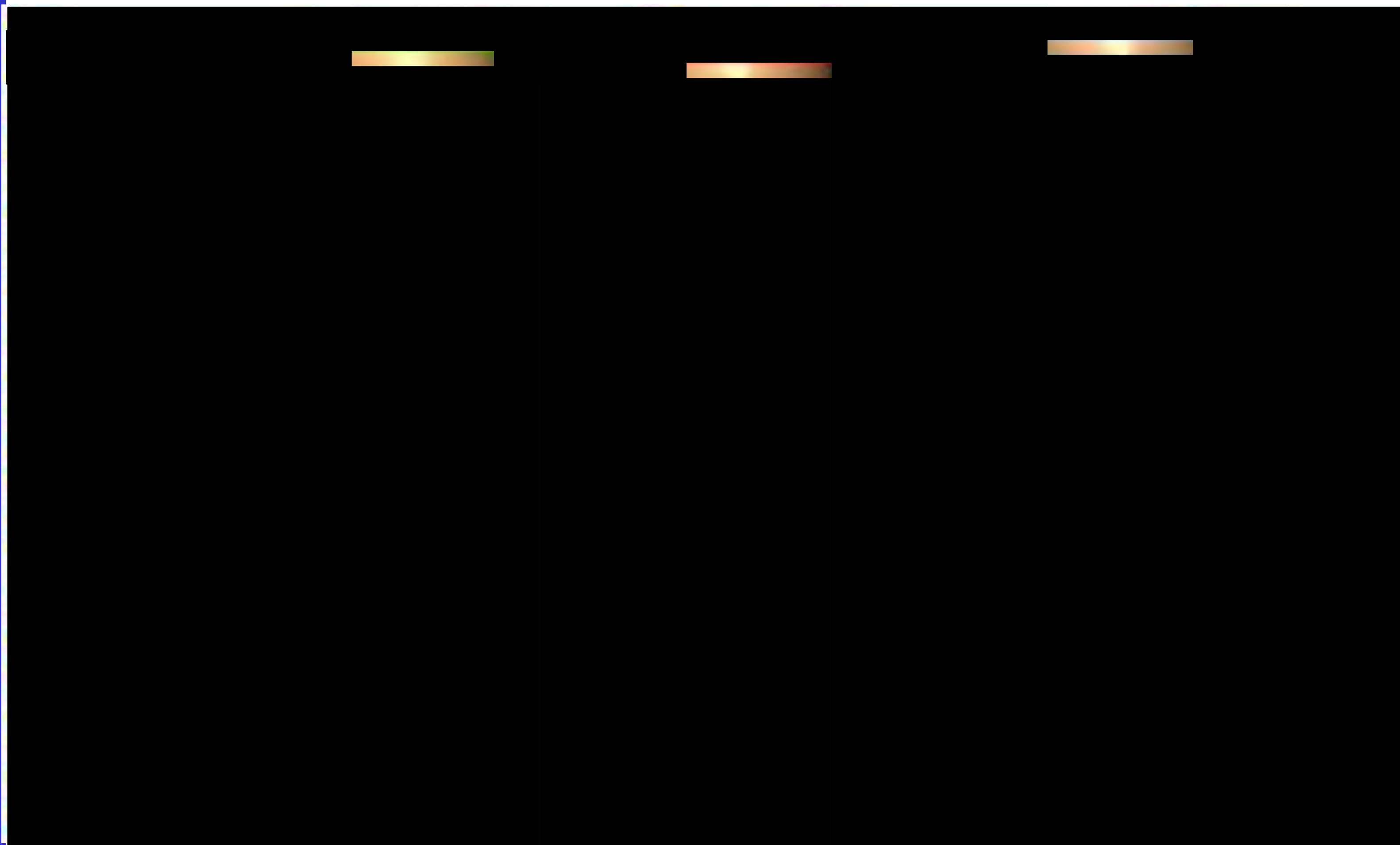
The perception of color



The balls all have the same color…

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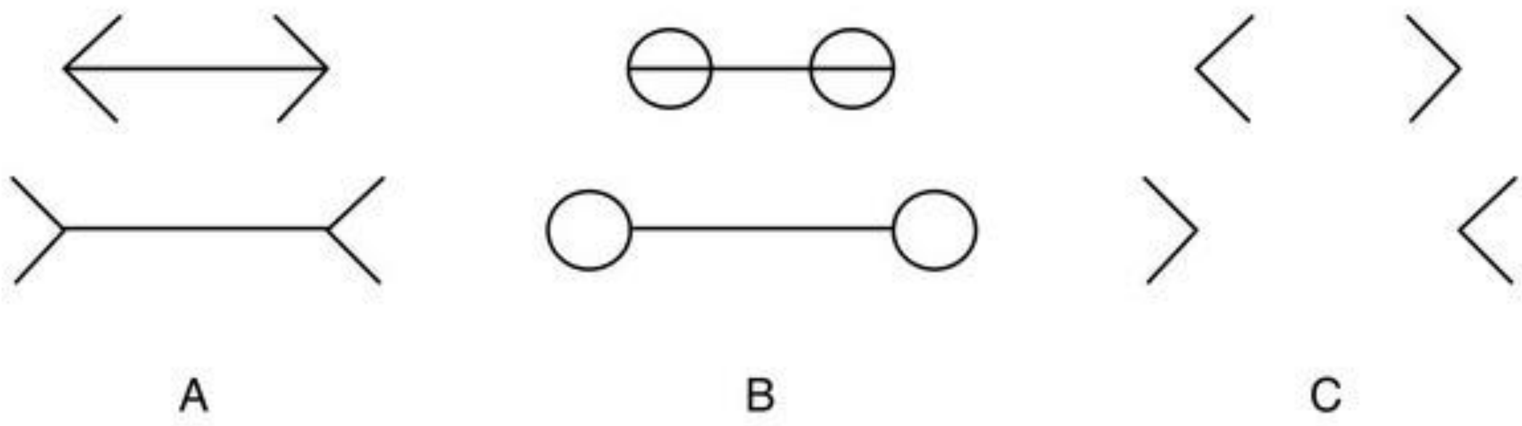
The perception of length



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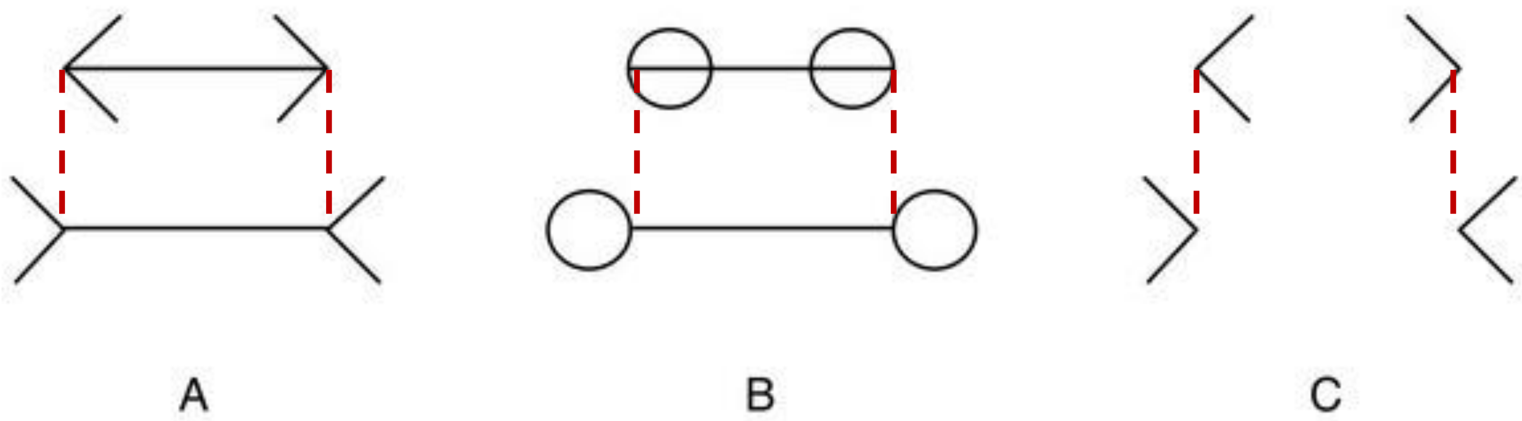
The perception of length



The horizontal lines are equally long…

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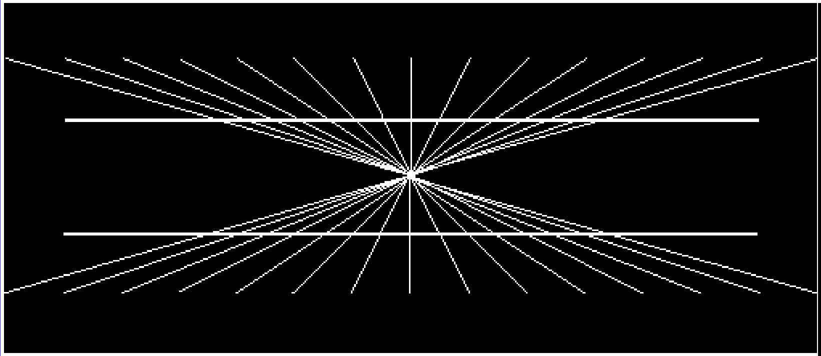
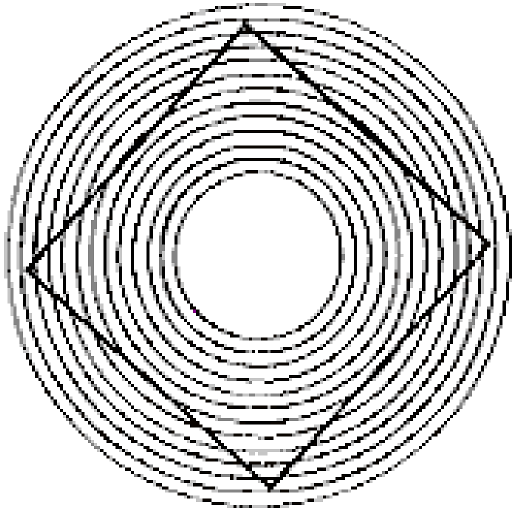
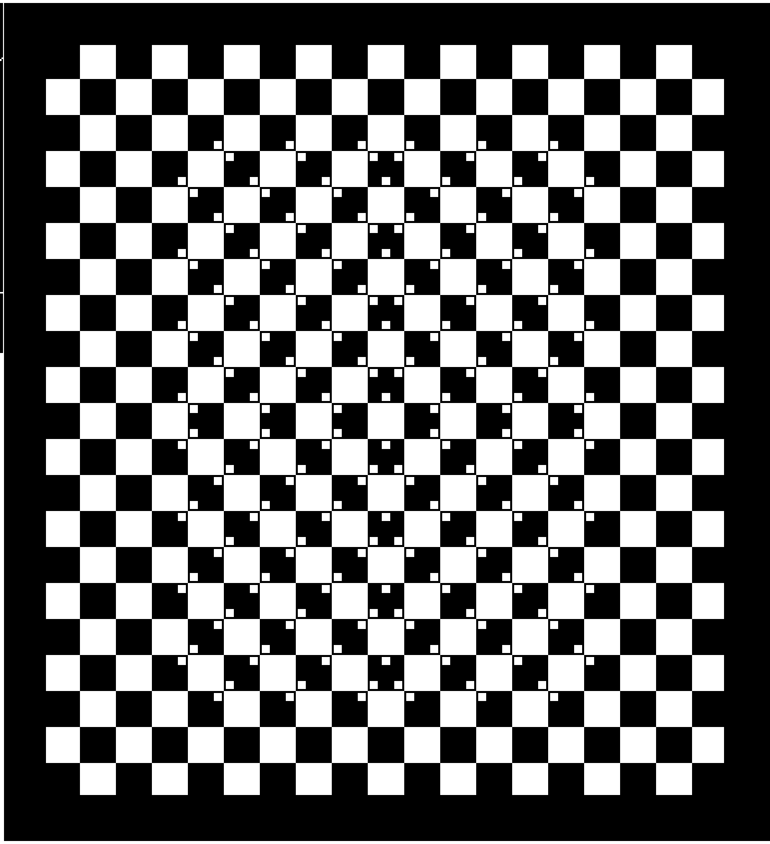
The perception of lines being straight







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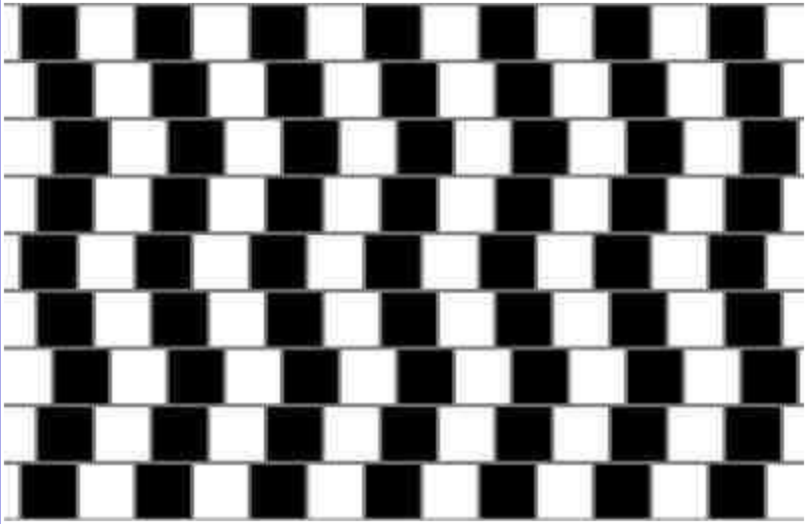
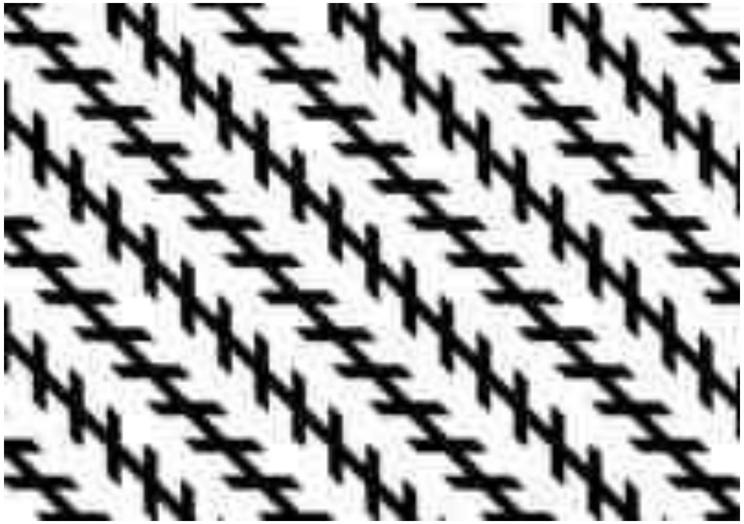
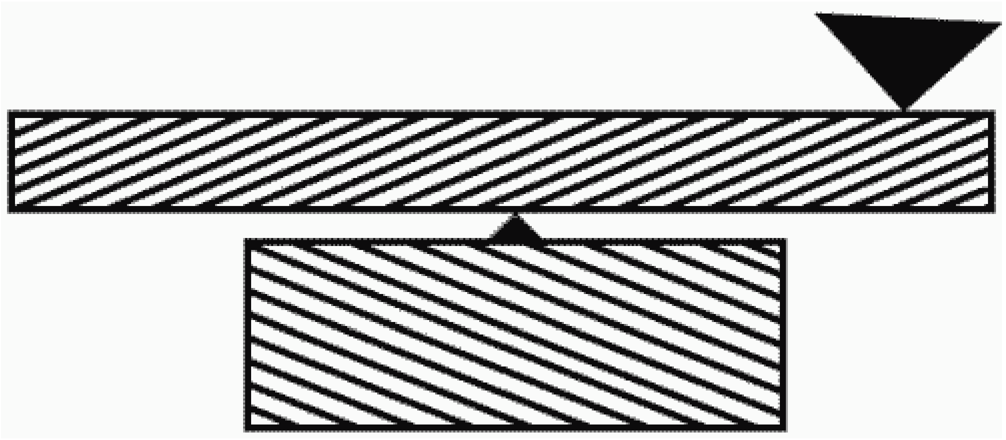
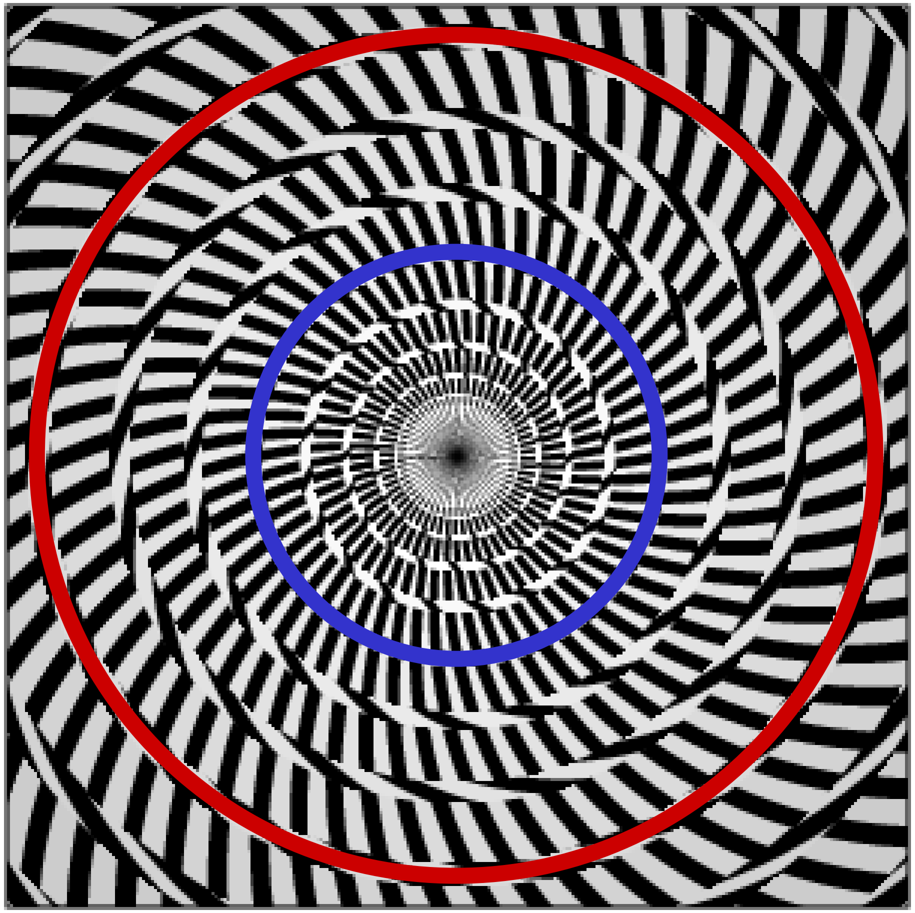
The perception of parallelism







The perception of curvatures



Illusions : interference of differently oriented patterns via adaptation

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The perception of motion

The `barber pole' rotates about the vertical, it does not translate vertically…

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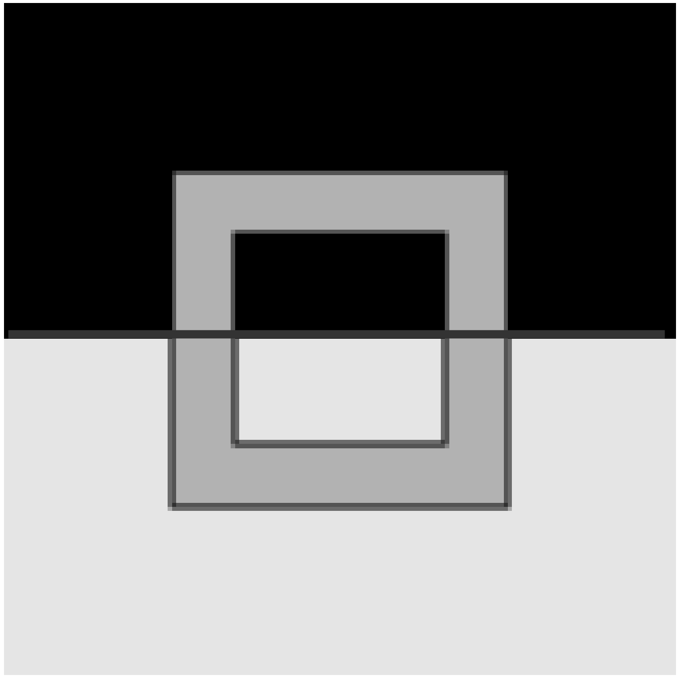
It’s not that more context solves it all…

there is literally more than meets the eye,
i.c. a lot of massively parallel processing



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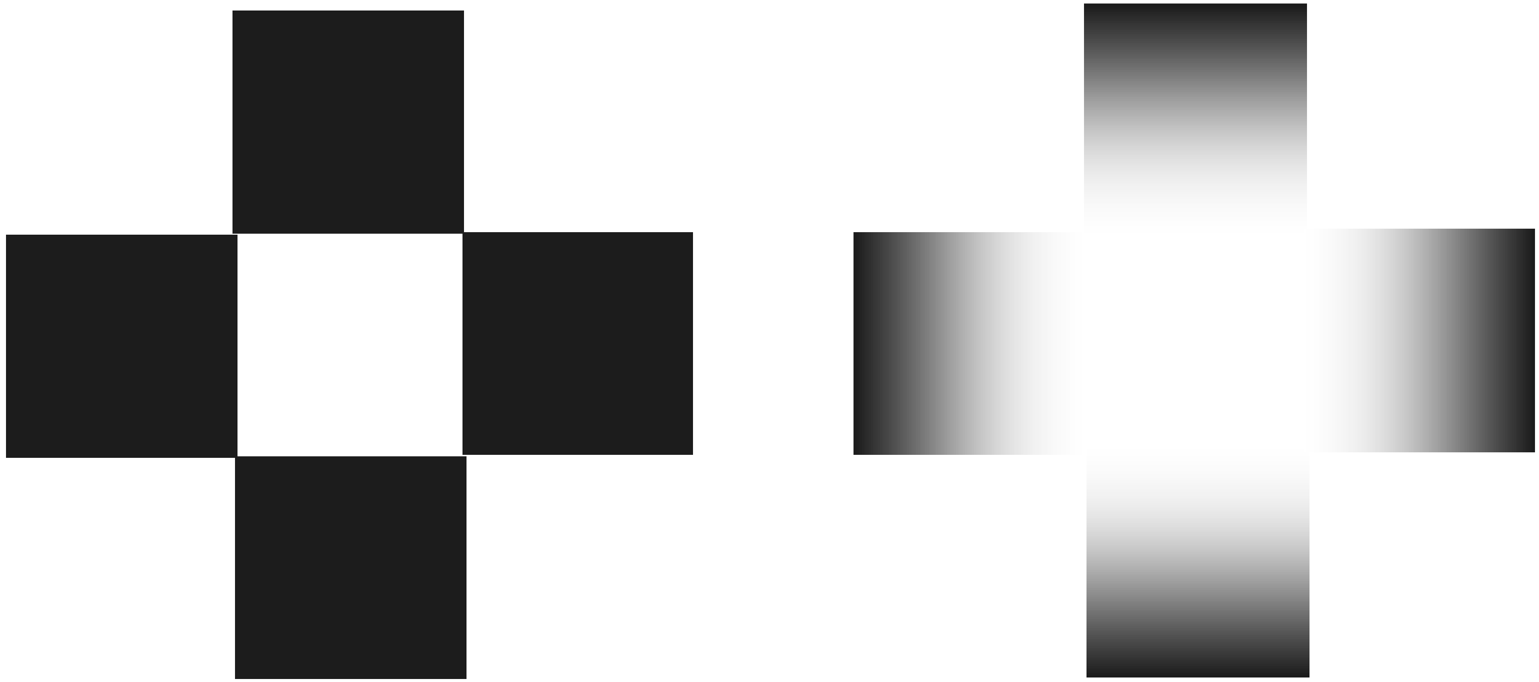
The perception of intensity



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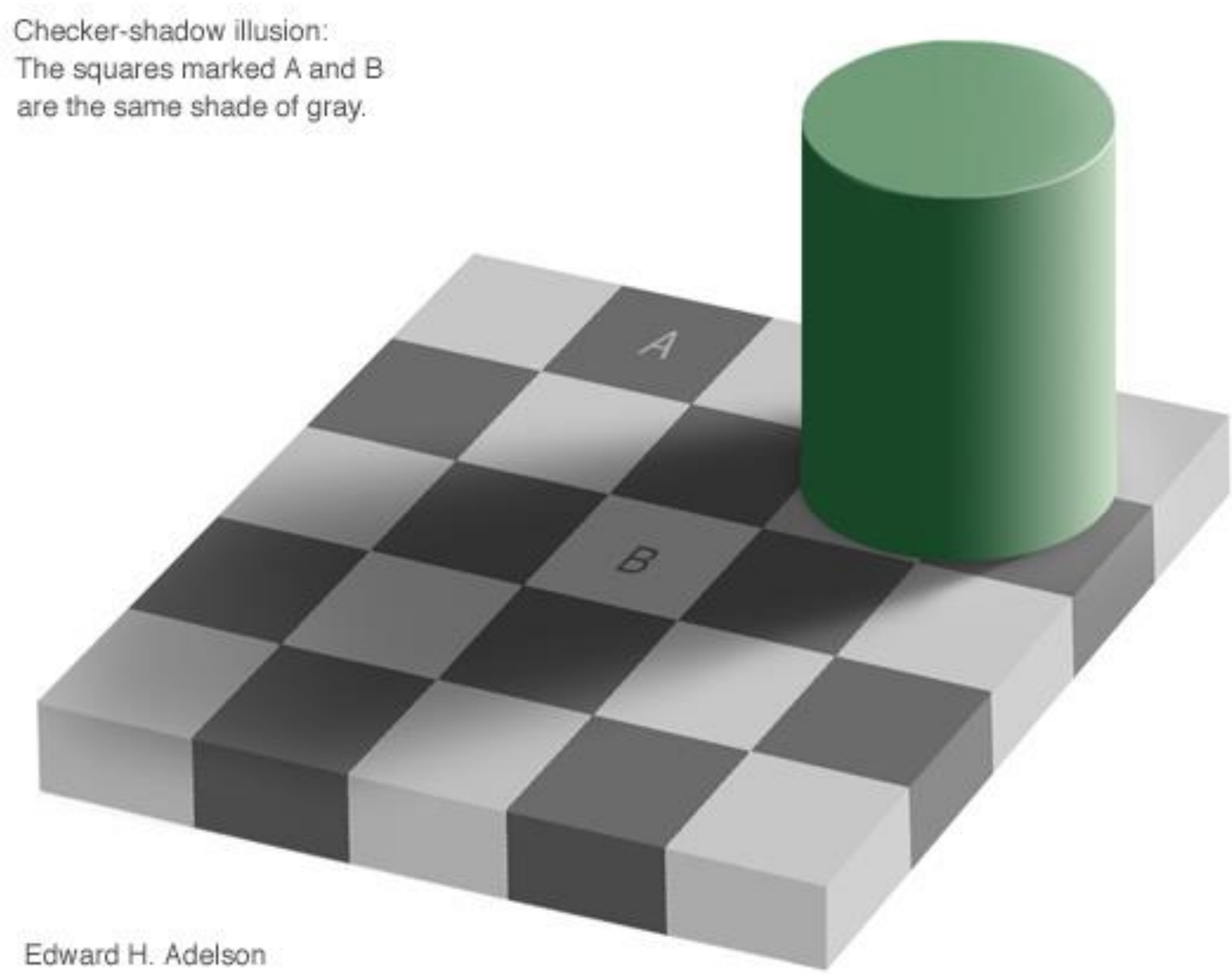
The brain factors out illumination



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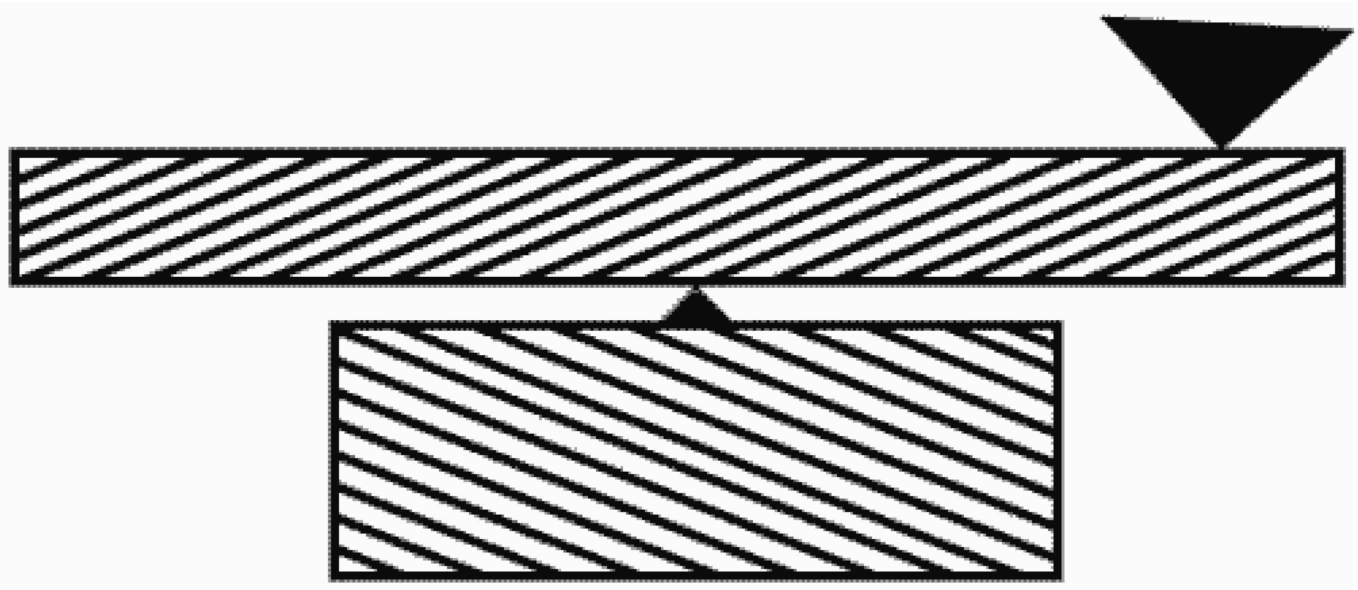
Parallelism again…



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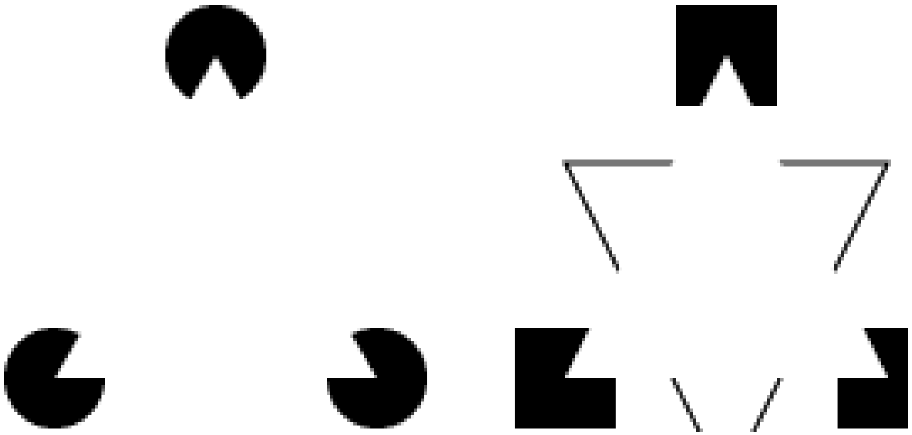
Kanisza illusion



Fill-in : averaging of perceived contrast at edges over regions possibly obtained via extrapolation of the edges… in any case *such illusion seems to help people to detect patterns in the world.*

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The role of context

Human vision: Biederman, Bar & Ullman, Palmer, …

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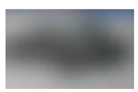
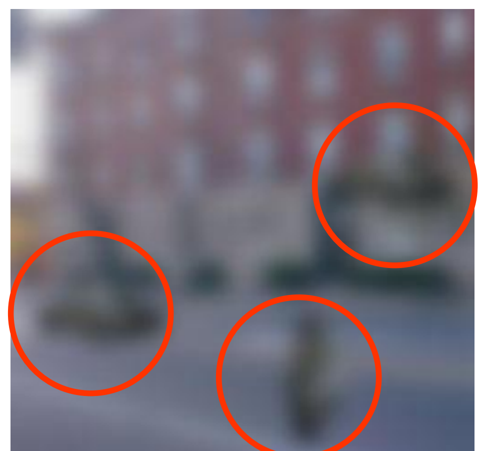
The role of context

All encircled patterns are identical:





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The role of context

Person?

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The role of context

Person?

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The role of context

Person?

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The role of context

Person?

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The role of context

human vision is much more than a bottom-up process of subsequent signal processing steps.

Car?

The central take-home message:

Effective vision needs more than sheer filtering and measuring

This introductory lecture:

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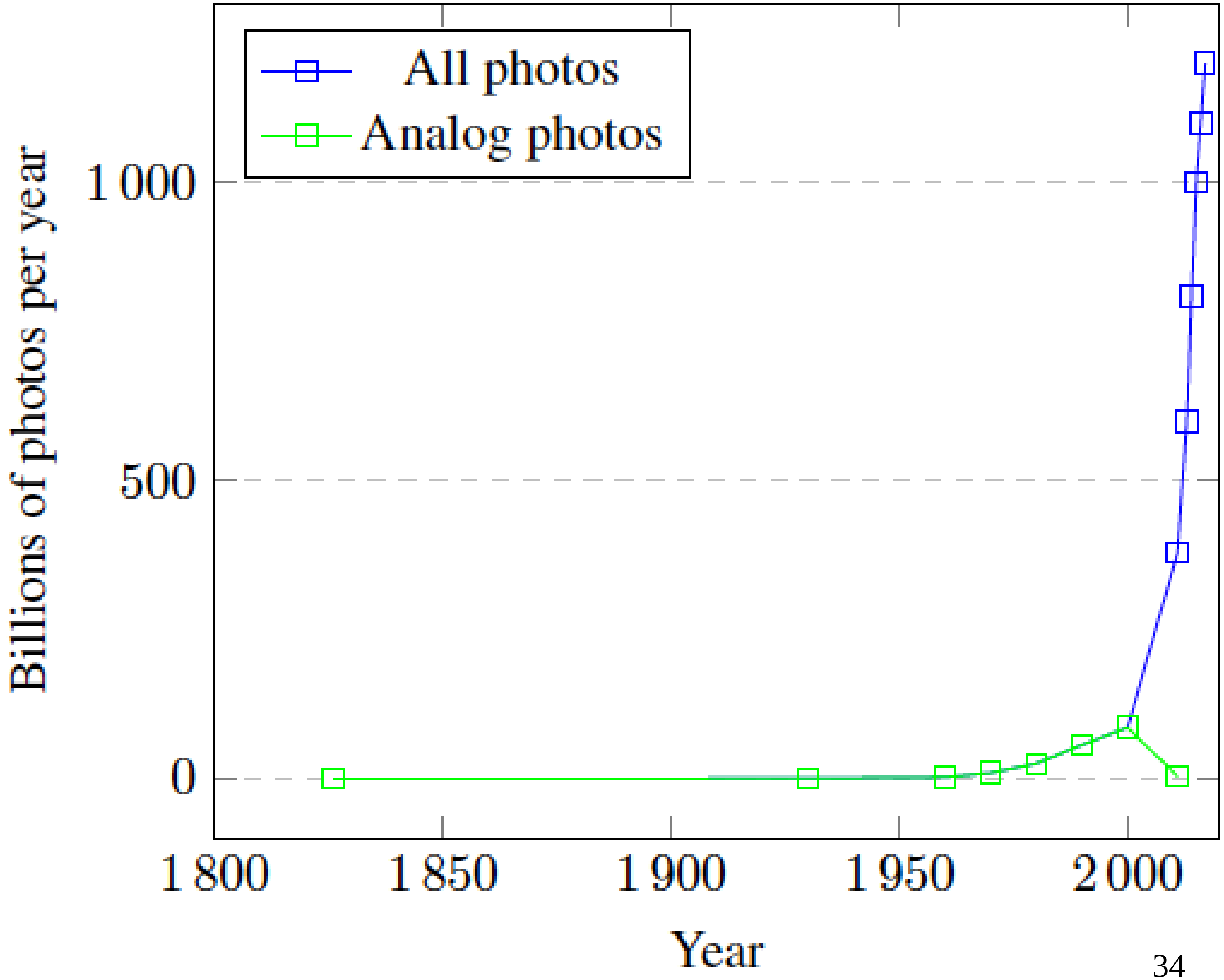
The explosion of photography



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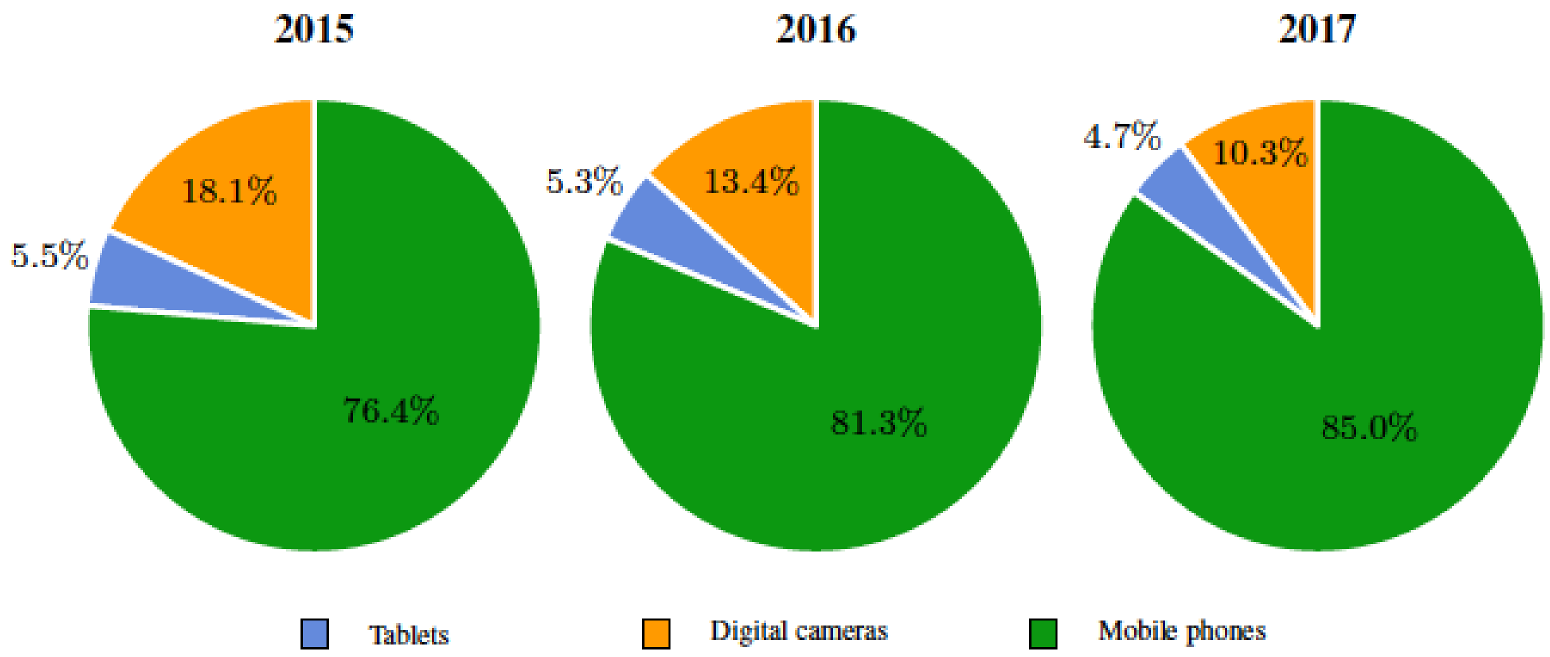
The explosion of photography



Easier than ever to take a photo
The cost is extremely low (cheap memory)
Most people carry a camera most of the time

The development of computer vision apps

Most early applications where found in production environments, as these *allow for controlled conditions* and *have little uncertainty*

some areas do not allow for much control: medical IP, remote sensing, surveillance, etc., and became somewhat independent areas of specialization

currently CV is conquering other less controllable areas by storm

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Ex App: image enhancement: mobile -> DSLR

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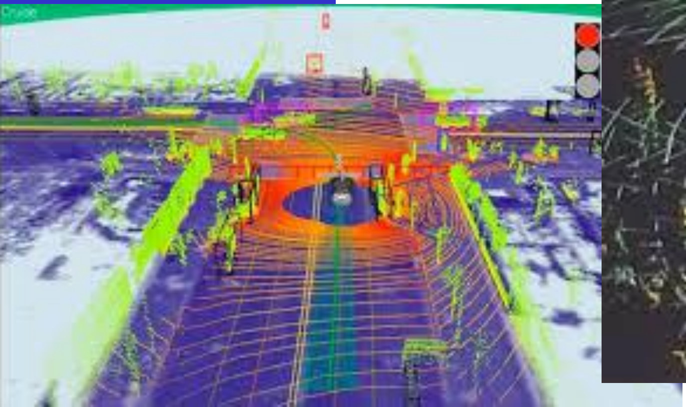
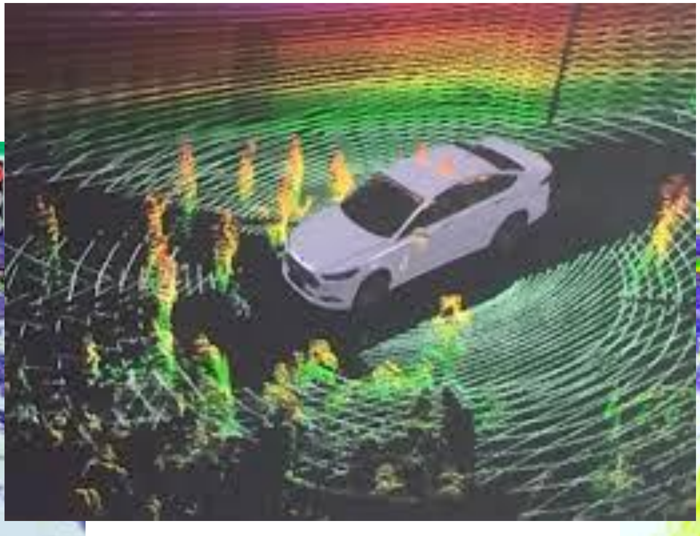
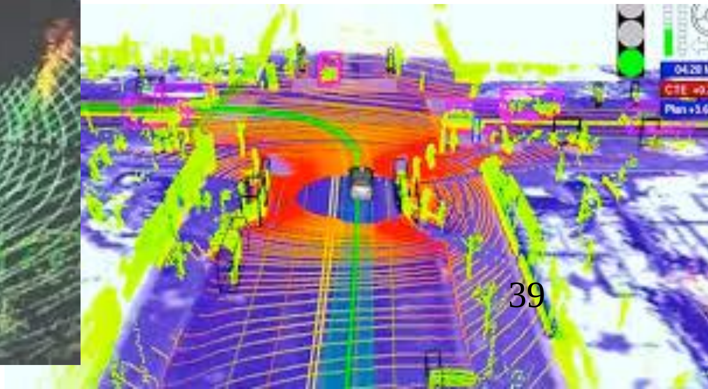
Ex App: synthetic face generation

https://miro.medium.com/max/1176/1*LZp9nkzbSk8v6cpwp8CD8g.gif

Ex App: autonomous vehicles







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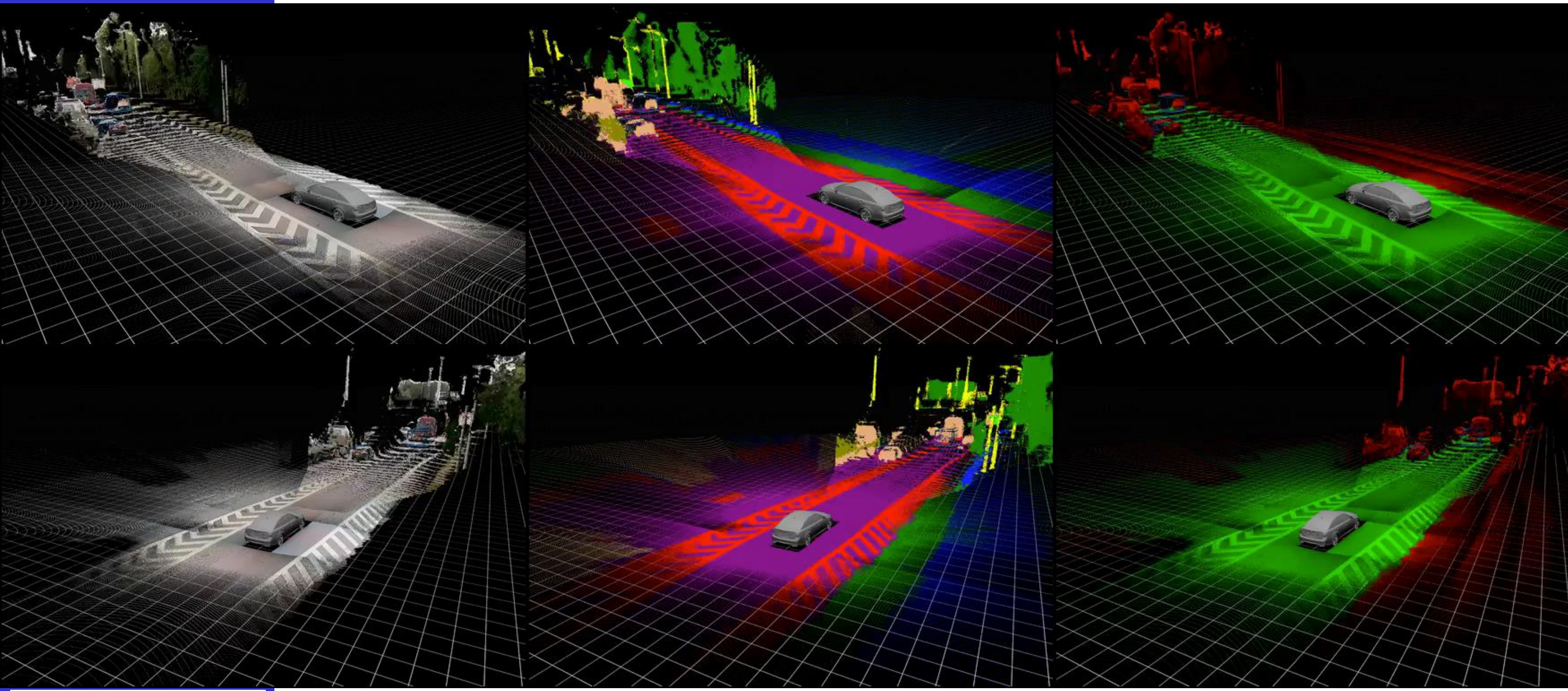
Ex App: autonomous vehicles

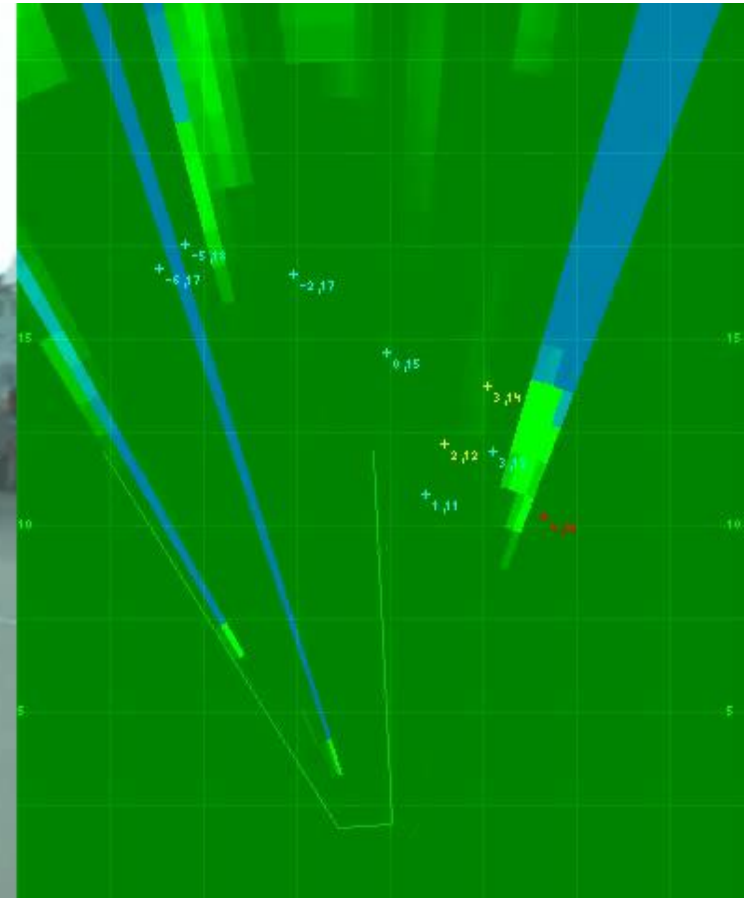
car detection:

Ex App: autonomous vehicles

putting vision modalities together:



Ex: autonomous mobile platform



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Ex App: image retrieval, captioning, …

Describes without errors	Describes with minor errors	Somewhat related to the image	Unrelated to the image

A person riding a motorcycle on a dirt road.

Two dogs play in the grass.

A skateboarder does a trick on a ramp.

A dog is jumping to catch a frisbee.

A group of young people playing a game of frisbee.

Two hockey players are fighting over the puck.

A little girl in a pink hat is blowing bubbles.

A refrigerator filled with lots of food and drinks.

A herd of elephants walking across a dry grass field.

A close up of a cat laying on a couch.

A red motorcycle parked on the side of the road.

A yellow school bus parked in a parking lot.

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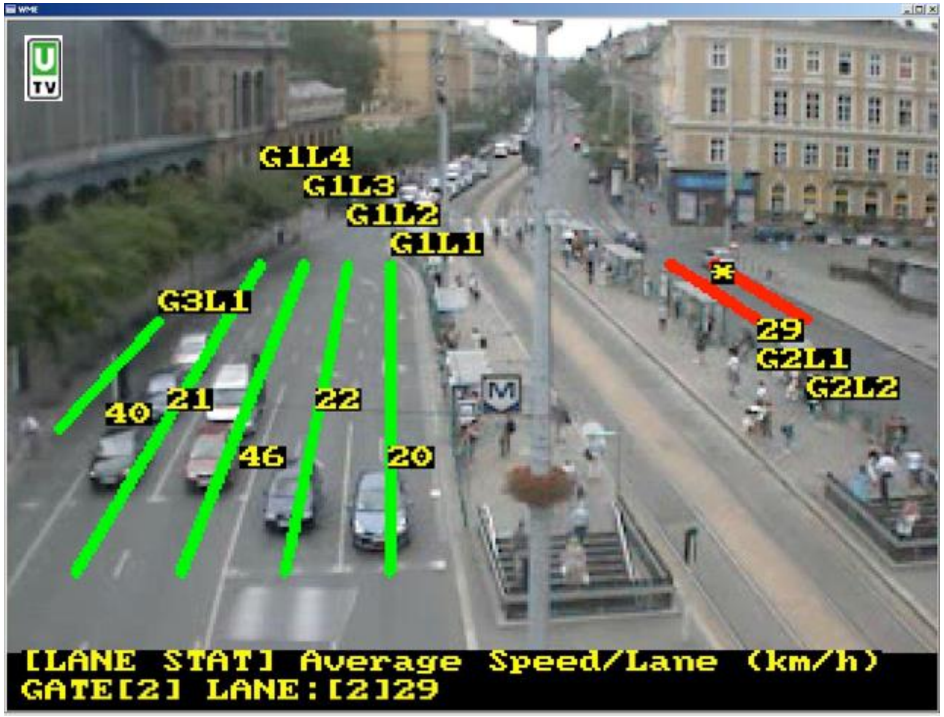
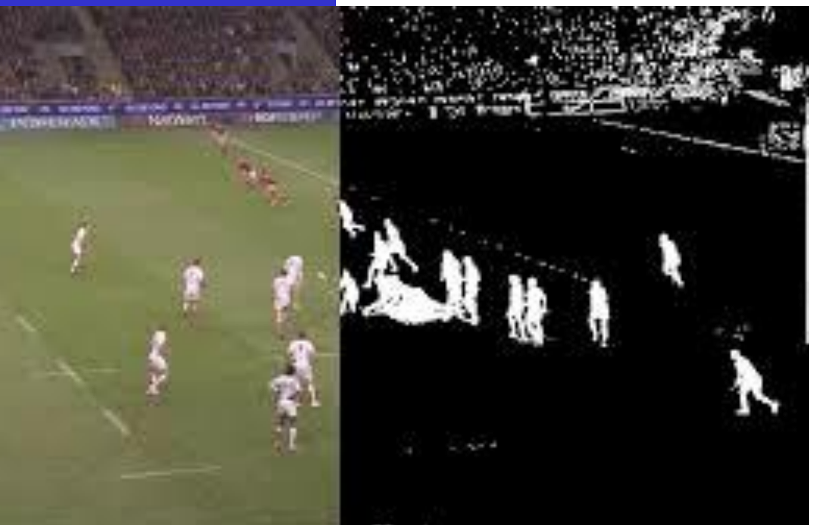
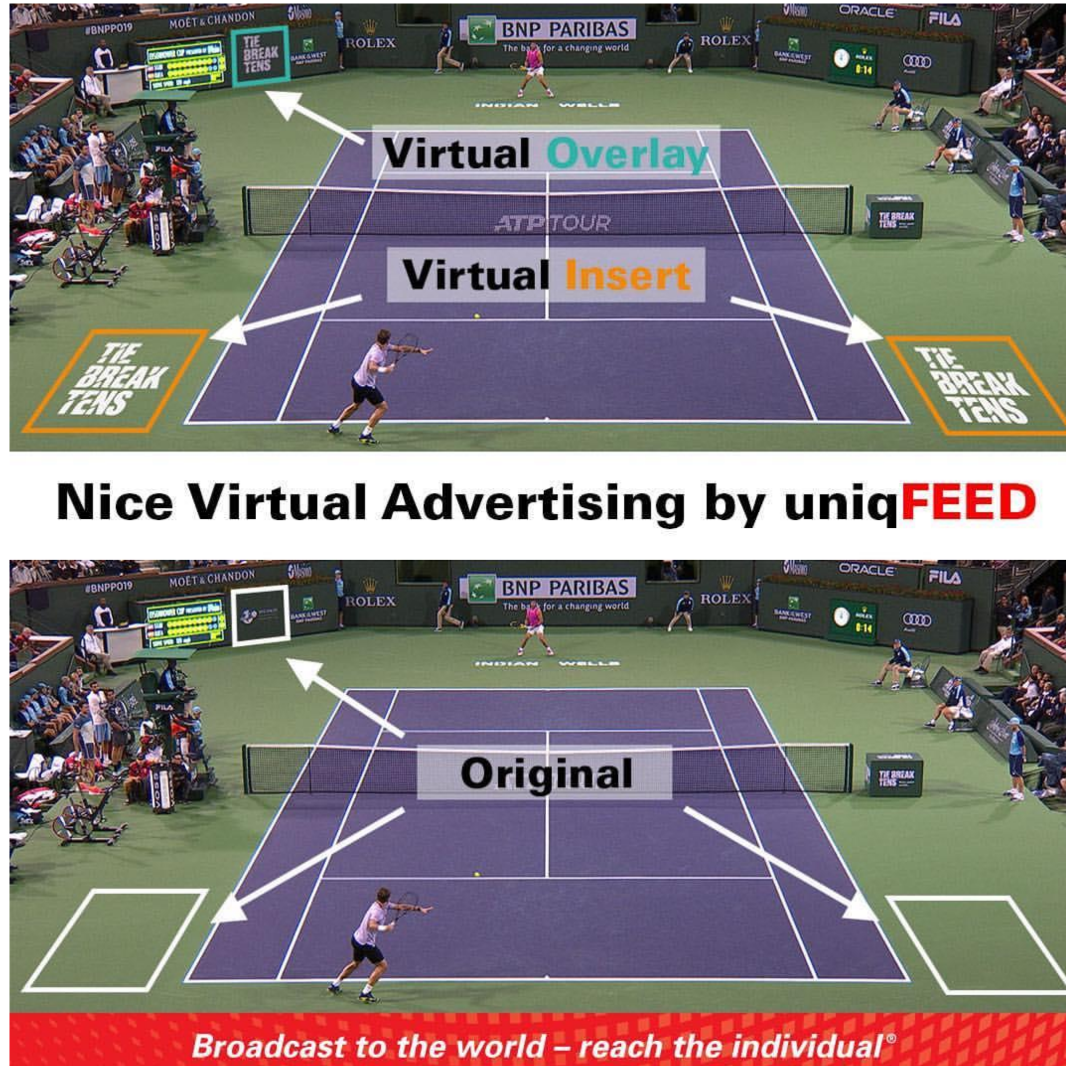
Ex App: visual surveillance



Ex App: Augm. Reality, eg sports





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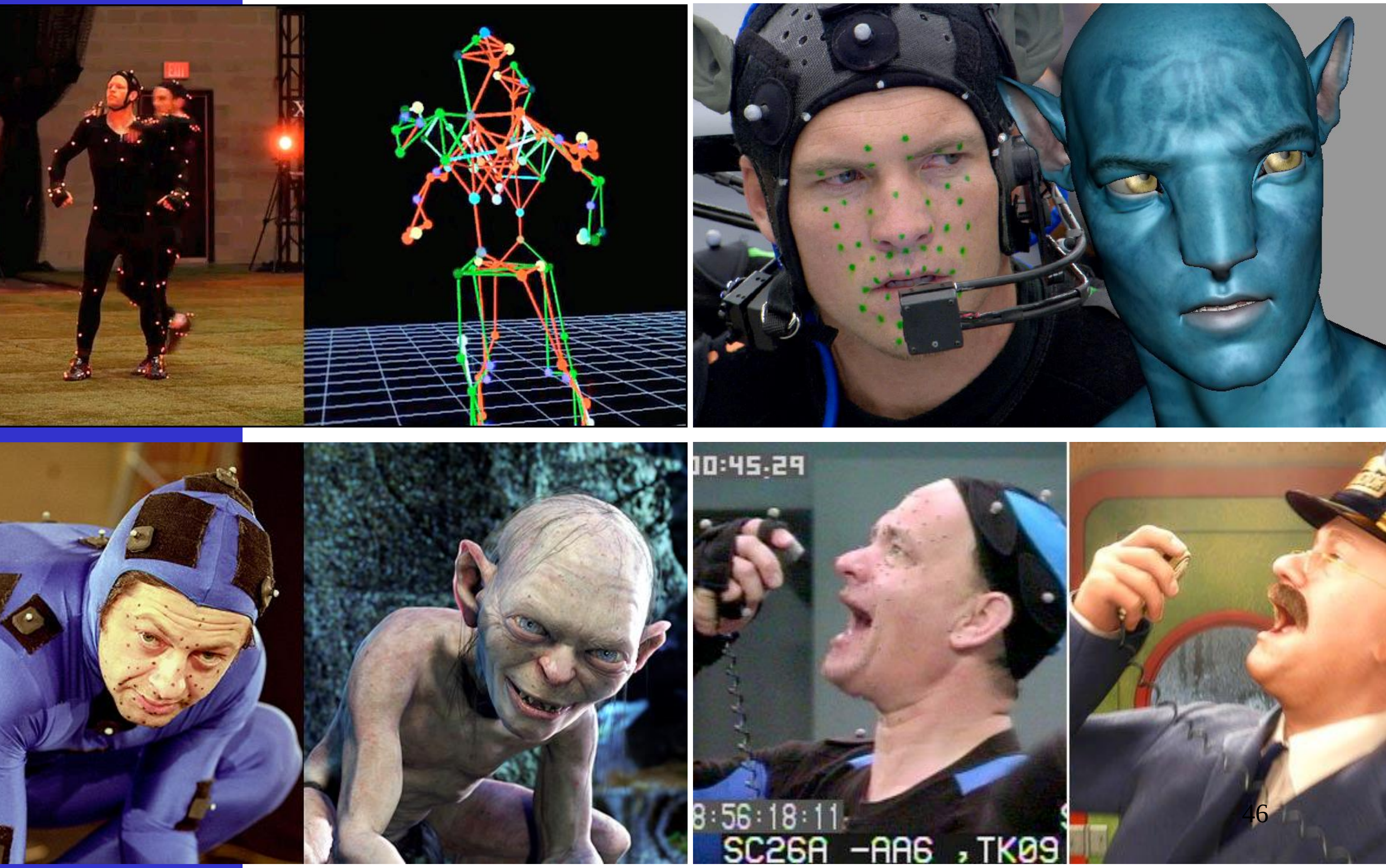
Ex App: motion capture for movies/games



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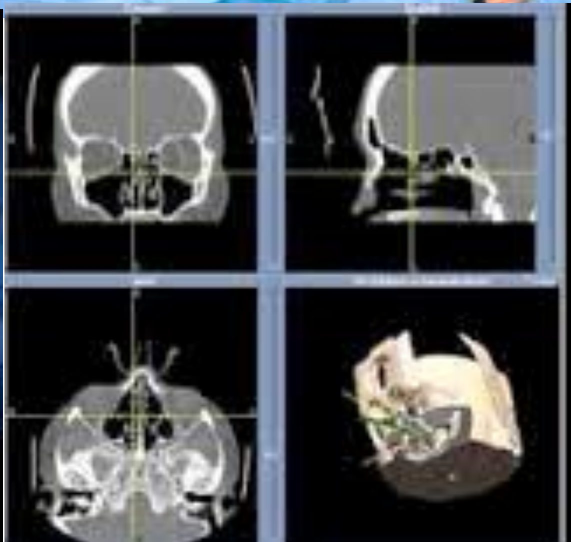
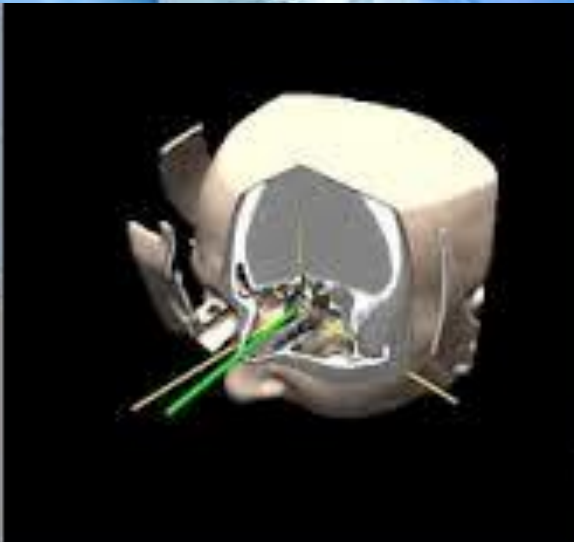
Ex App: computer-assisted surgery





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Ex App: mobile mapping

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The central take-home message:

It is feasible now to let most things see and interprete their environment

This introductory lecture:

1. human perception
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And then there was Light…

- no vision without light…
- … because it is influenced by objects

"What the...?"

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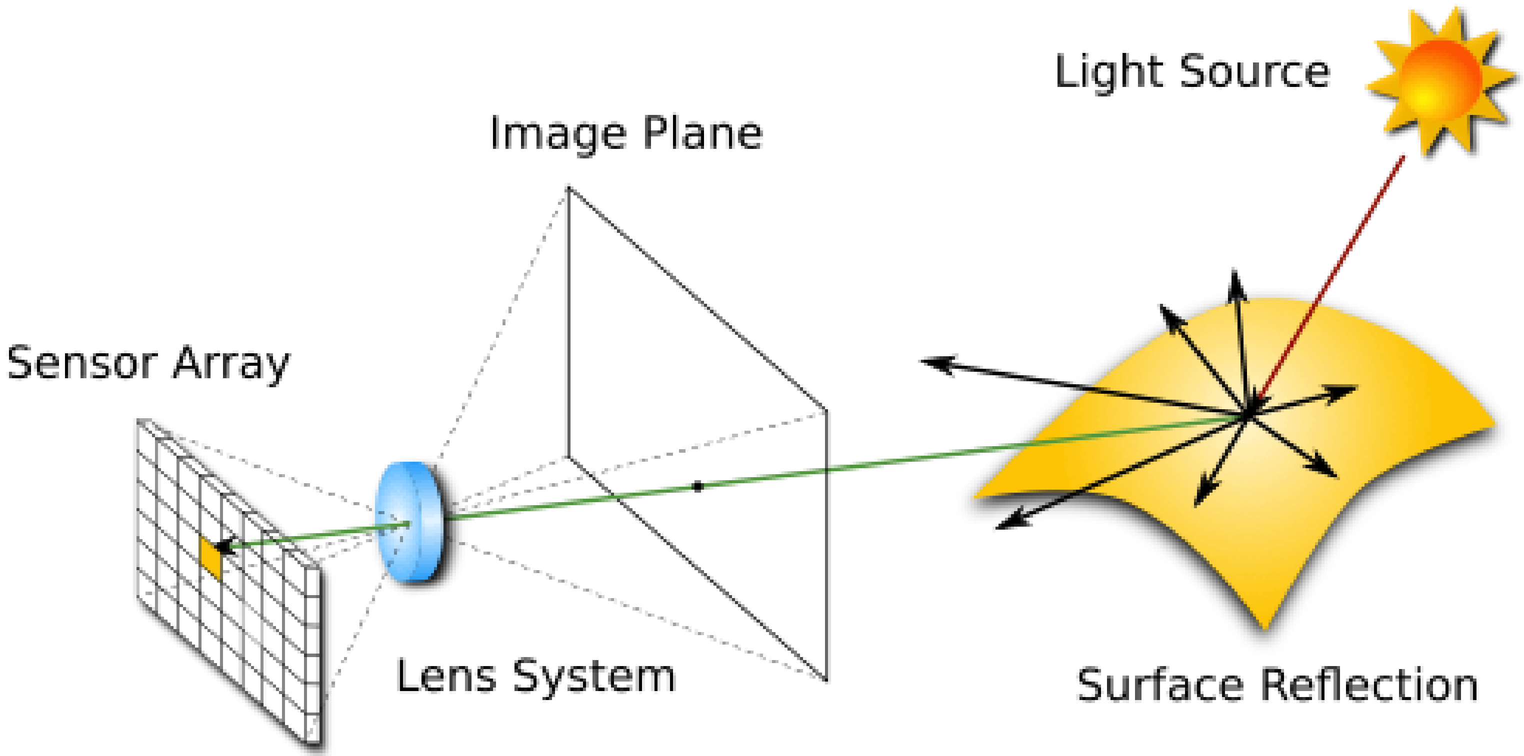
Kickoff: the light, surface, lens & cam



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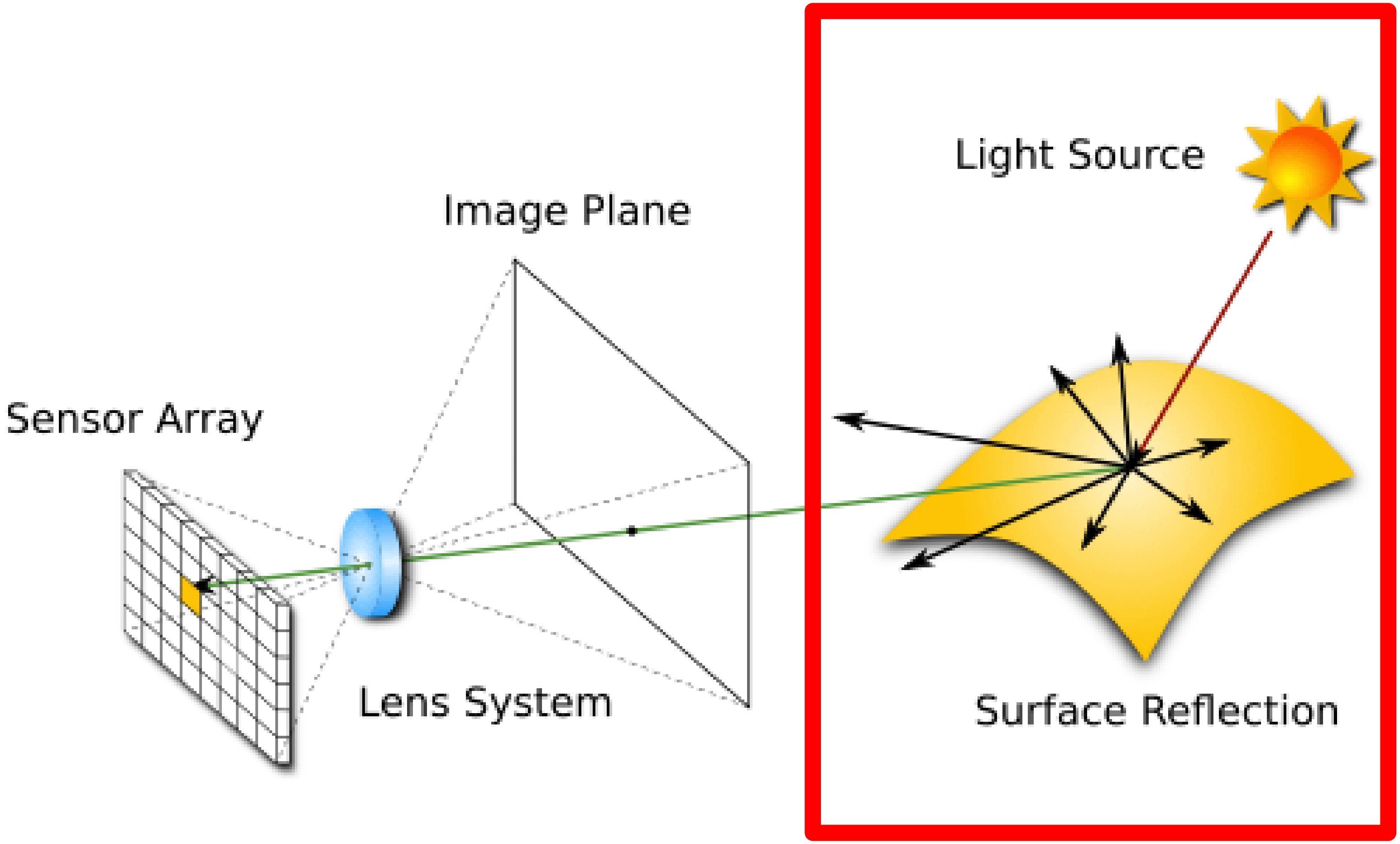
Kickoff: the light, surface, lens & cam



topics

- the nature of light
- interactions with matter

Levels of optical analysis

1. Geometrical optics
2. Physical optics, or
3. Quantum-mechanical optics

wave character

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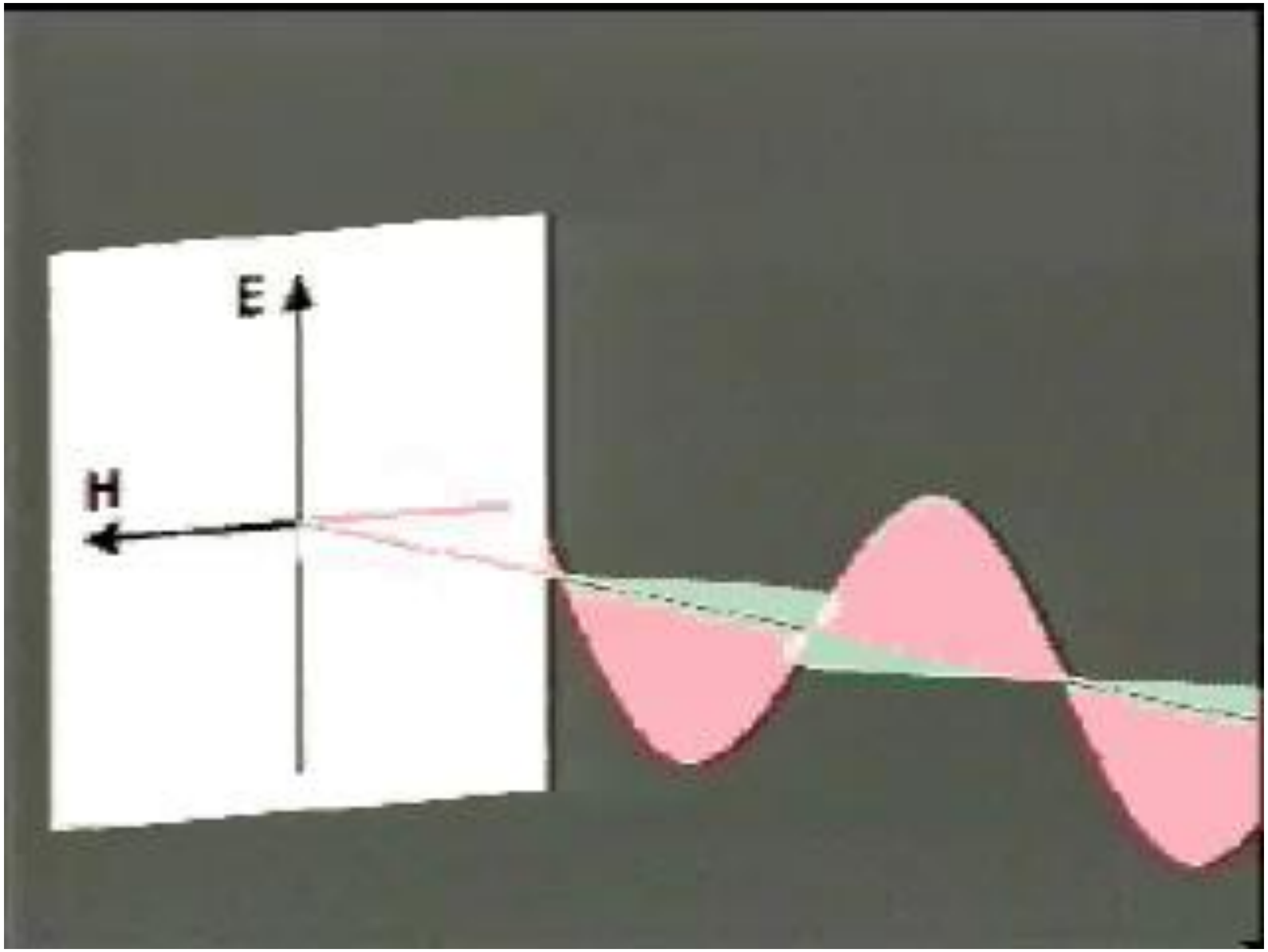
Light as electromagnetic waves



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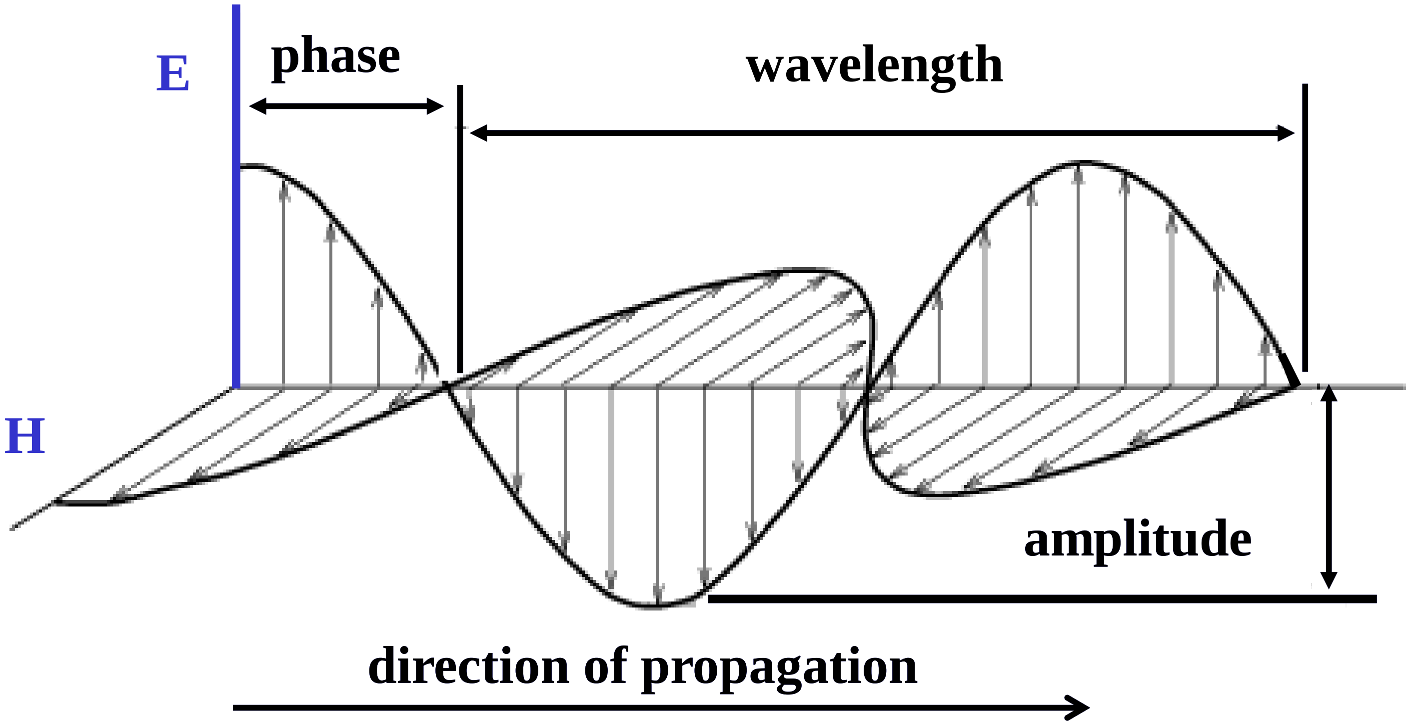
Light as electromagnetic waves

Self-sustaining exchange of electric and magnetic fields



1. wavelength
2. direction
3. amplitude *E*
4. phase
5. direction of polarisation

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The spectrum

Normal ambient light is a mixture of wavelengths, polarisation directions, and phases

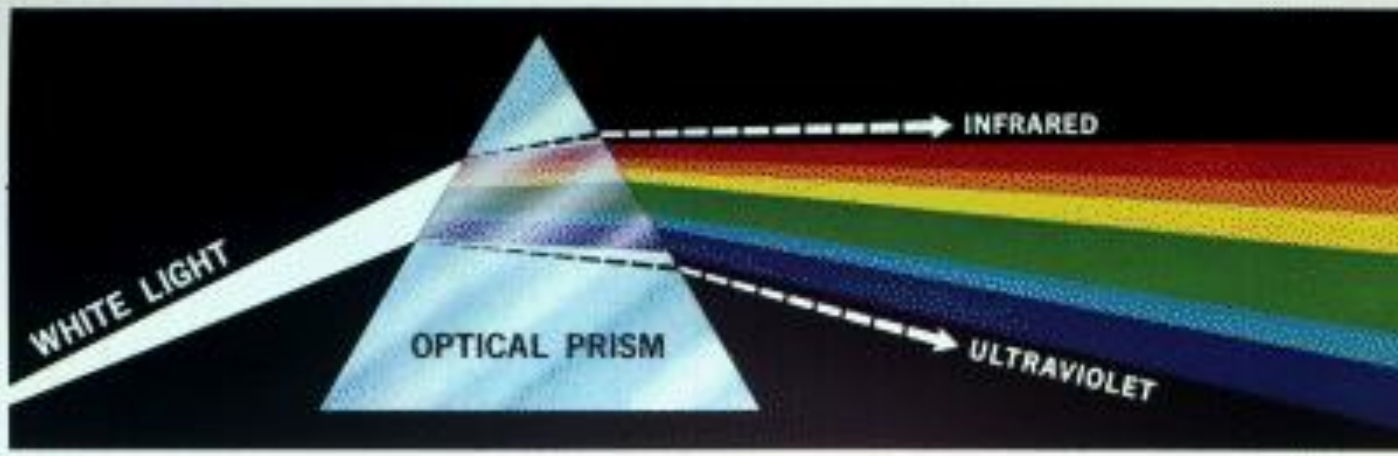
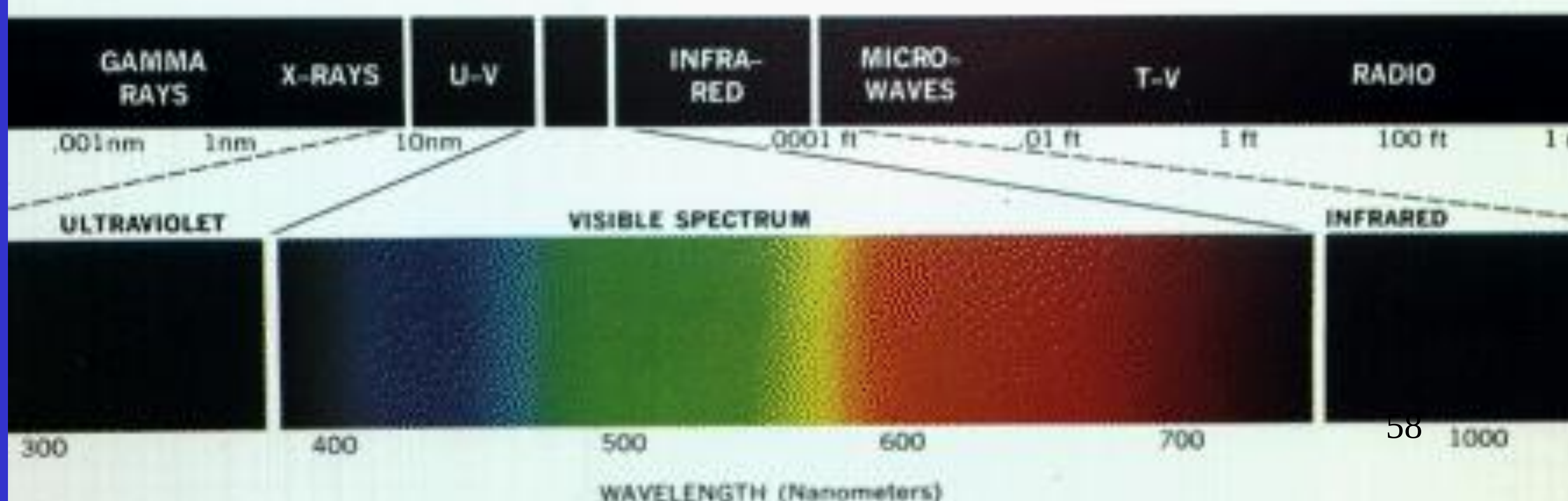


Plate I. Color spectrum seen by passing white light through a prism. (Courtesy of General Electric Co., Lamp Business Division.)



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The visible range of wavelengths

Wavelength (in *nm*)		Colour
380 - 450	→	violet
450 - 490	→	blue
490 - 560	→	green
560 - 590	→	yellow
590 - 630	→	orange
630 - 760	→	red

NOTE 1: From the observed colour you must not conclude that the light only contains wavelengths as given on the left

NOTE 2: Cameras may have different spectral sensitivities (i.e. also different from human vision)

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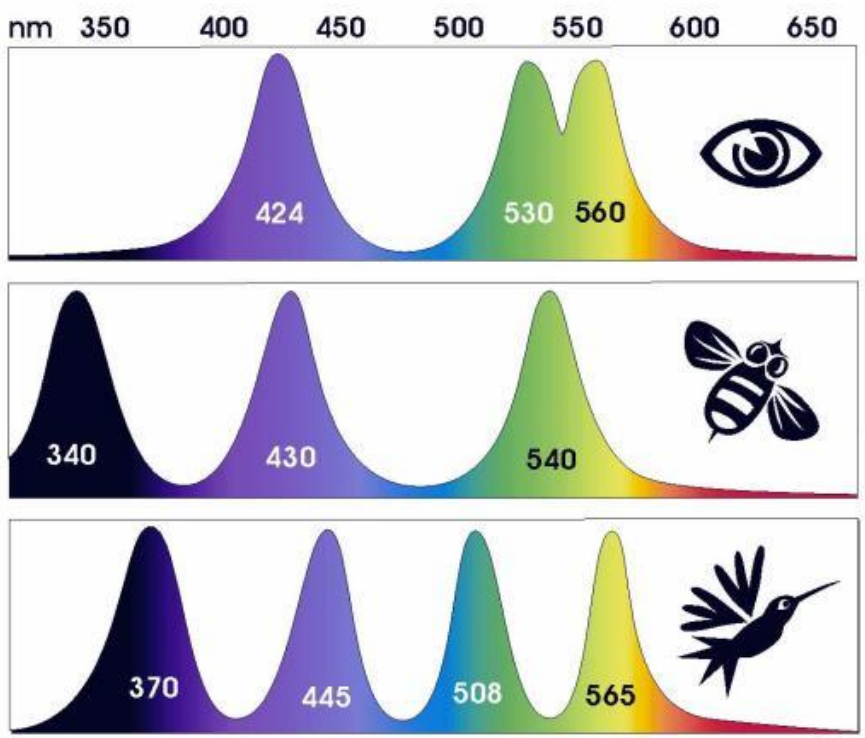
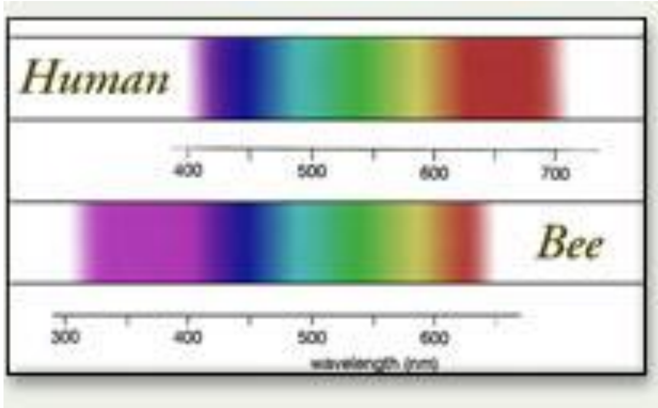
The visible range of wavelengths





NOTE 3: animals may have different spectral sensitivities (i.e. different from human vision), and may also have a different number of cone types (see lecture on colour), like 4 in most birds.

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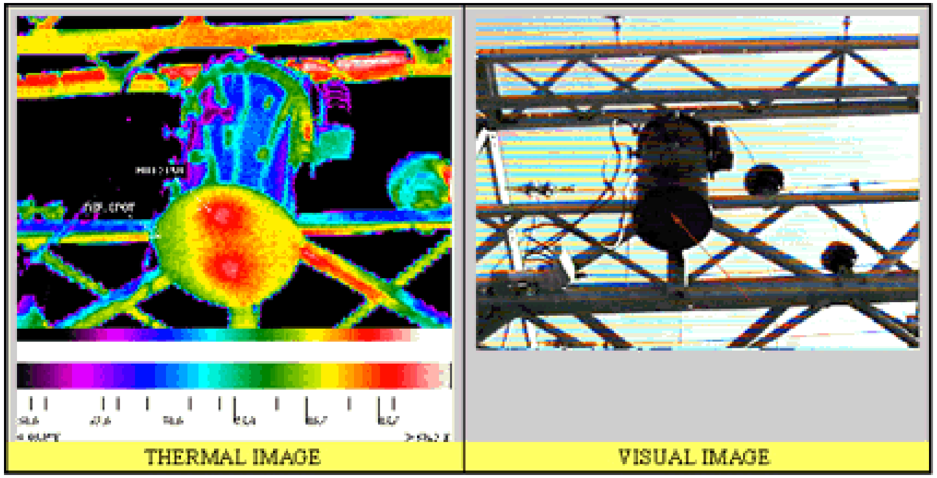
Also cams for non-visible `light', e.g. infrared



Overheating of transformer coils, with far IR

Near infra-red (NIR) space image

NRG -> RGB for visualization (notice the strong reflection in the NIR for vegetation)

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Interactions with matter

four types :

phenomenon	example
absorption	blue water
scattering	blue sky, red sunset
reflection	coloured ink
refraction	dispersion by a prism

+ diffraction

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Interactions with matter

four types :

phenomenon	example
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+ diffraction

Scattering

3 types depending on relative sizes of particles and wavelengths:

1. small particles: *Rayleigh* (strongly wavelength dependent)

2. comparable sizes: *Mie* (weakly wavelength dependent)

3. Large particles: *non-selective* (wavelength independent)

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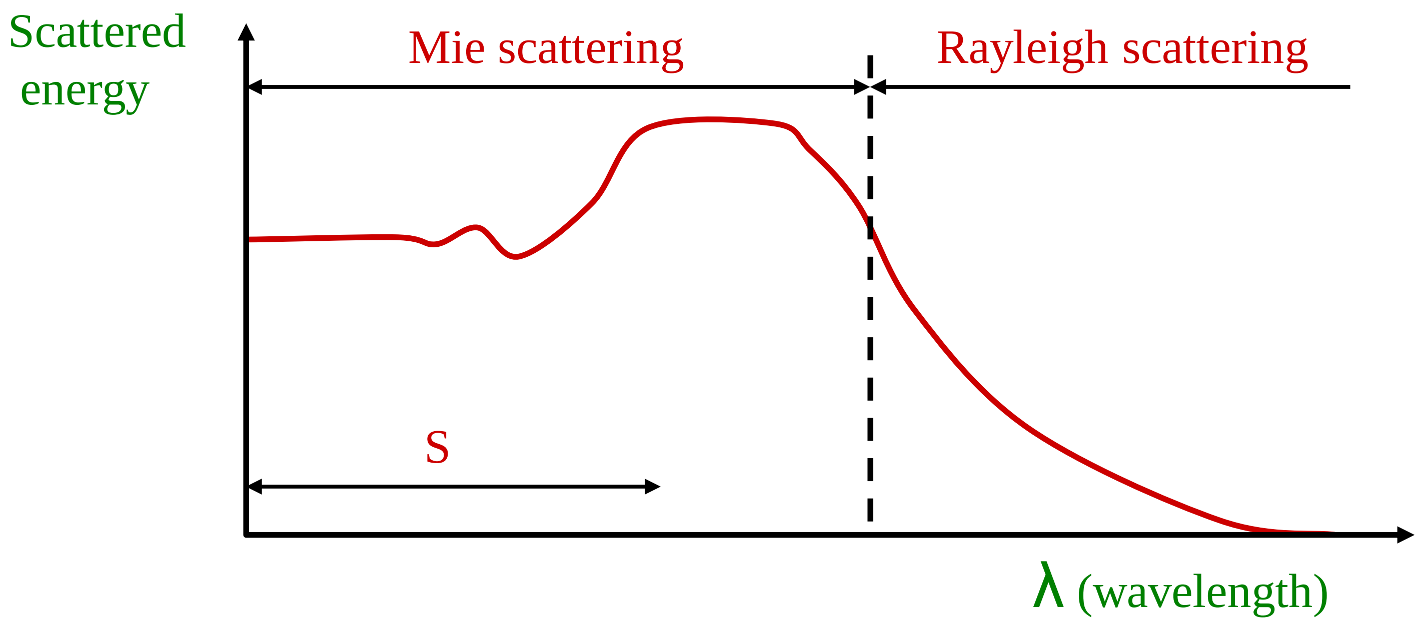
Wavelength dependence



Less haze in the infrared (long wavelengths -> little scatter)
Looking through clouds by radar (even longer wavelengths)
NOTE: without scatter we would wander mainly in the dark

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Atmospheric showcase

__Rayleigh:__
Tyndall effect (blue sky)
Red, setting sun

__Non-selective:__
Grey clouds

__Mie:__
Coloured cloud from volcanic eruption

Interactions with matter

four types :

phenomenon	example
absorption	blue water
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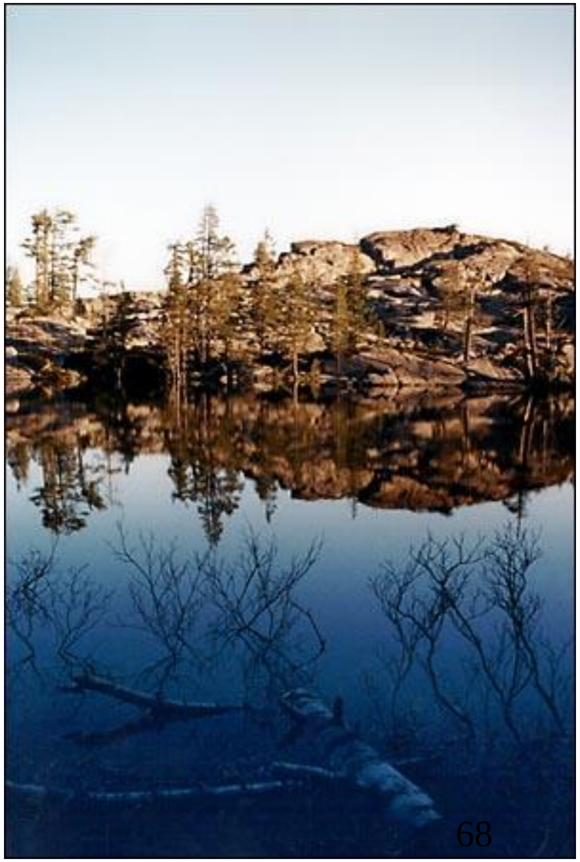
Mirror reflection



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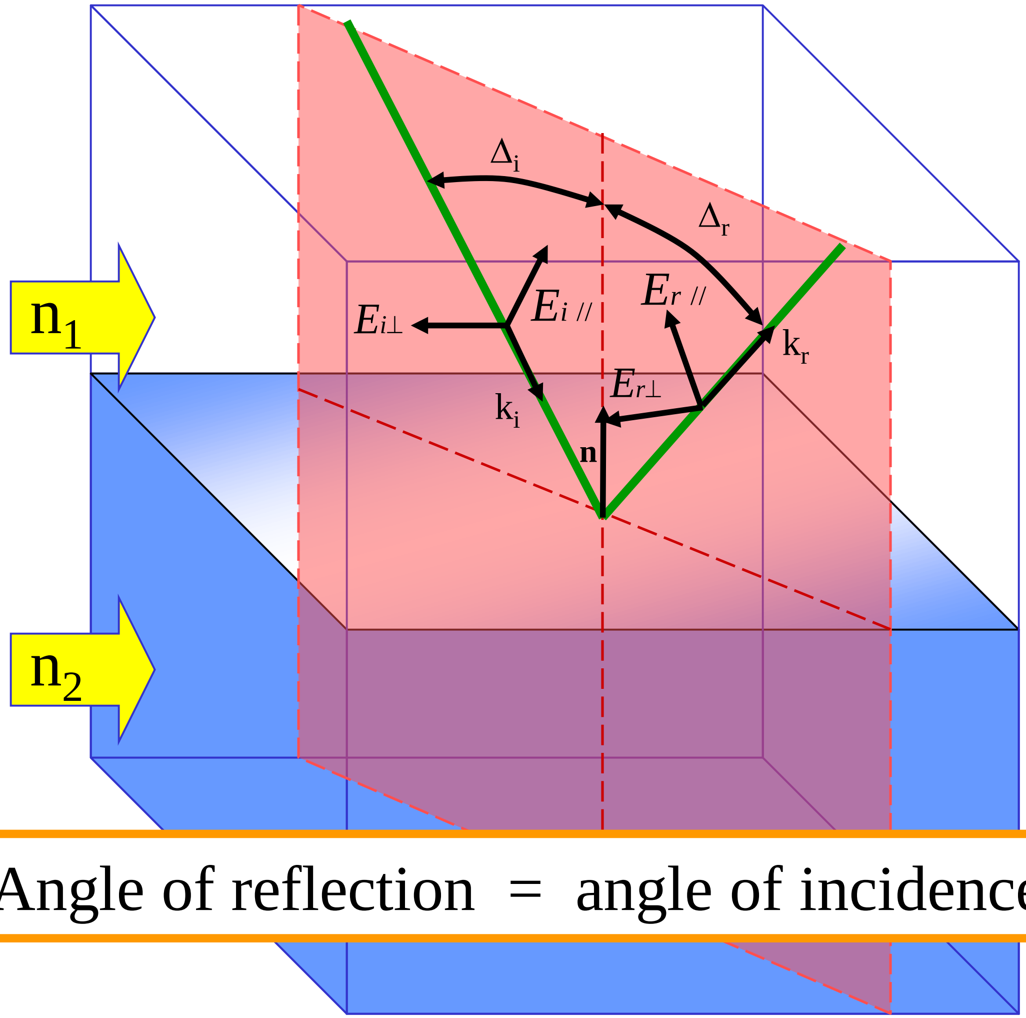
Mirror reflection



Angle of reflection = angle of incidence

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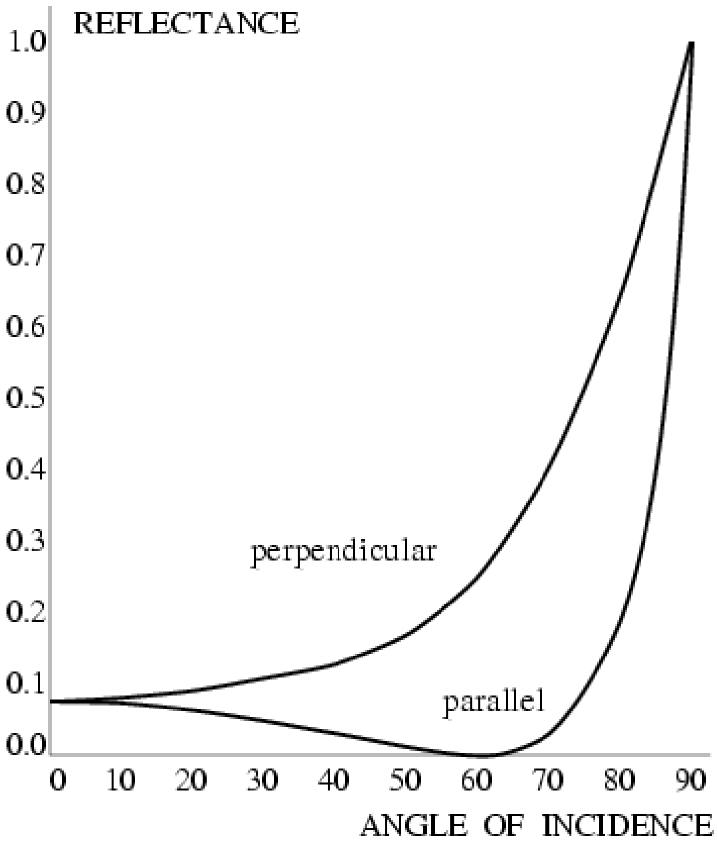
Mirror reflection : dielectric



Polarizer at *Brewster angle*

Full reflection at grazing angles

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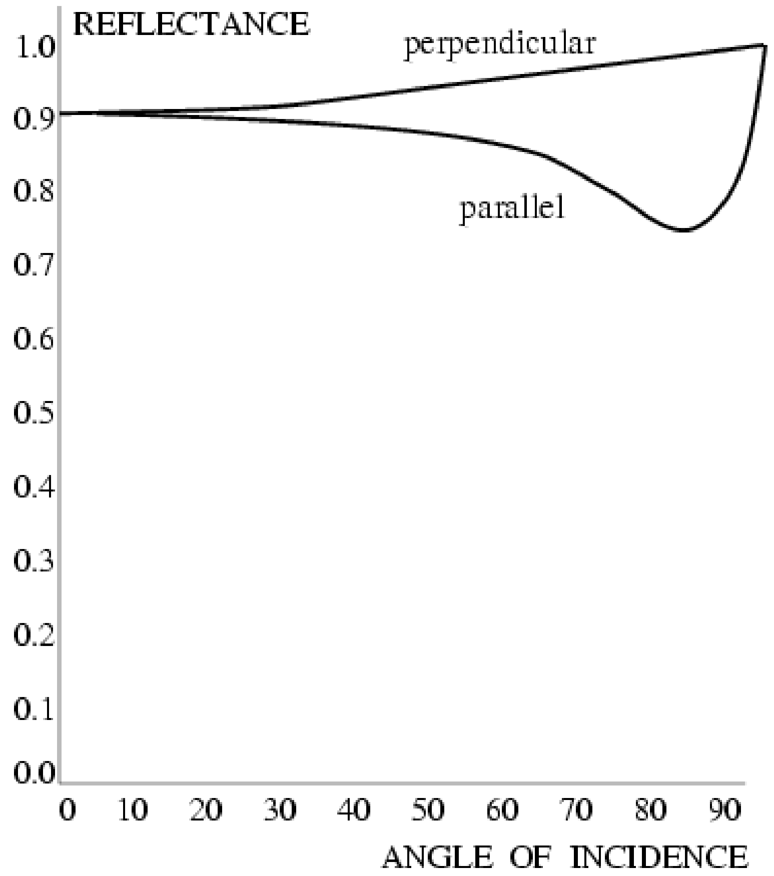
Mirror reflection : conductor



strong reflectors (under all angles)
more or less preserve polarization

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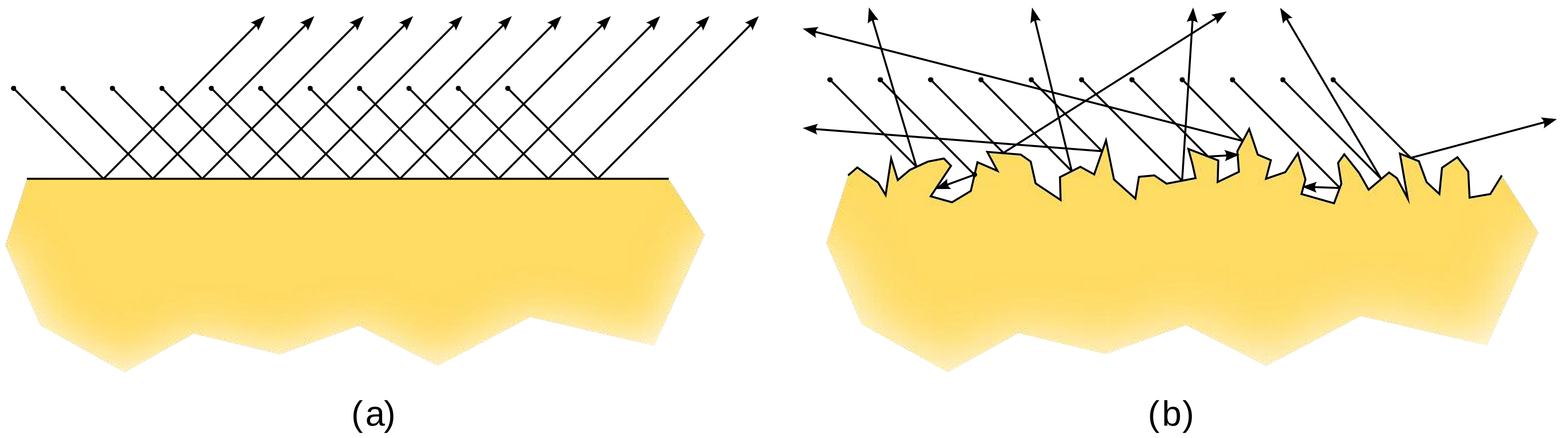
Roughness of surfaces leads to `diffuse' reflection



(a) Mirror or `specular' reflection, (b) diffuse reflection

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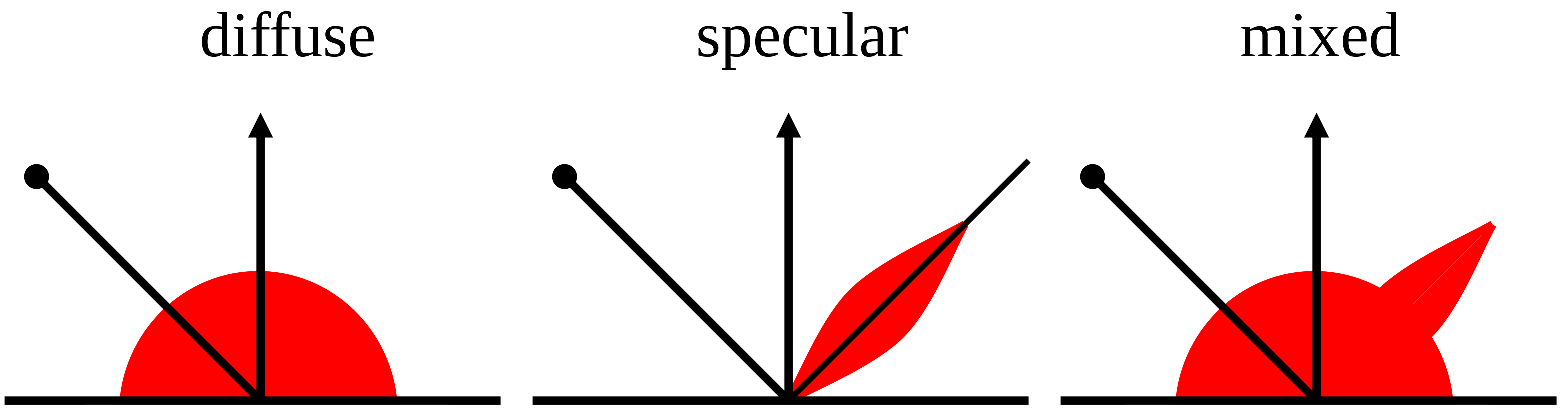
… and to mixed reflection for most real surfaces

three types of reflection :



Note : Lambertian example of diffuse reflection.

Under Lambertian reflection the surface looks equally bright when viewed from any direction

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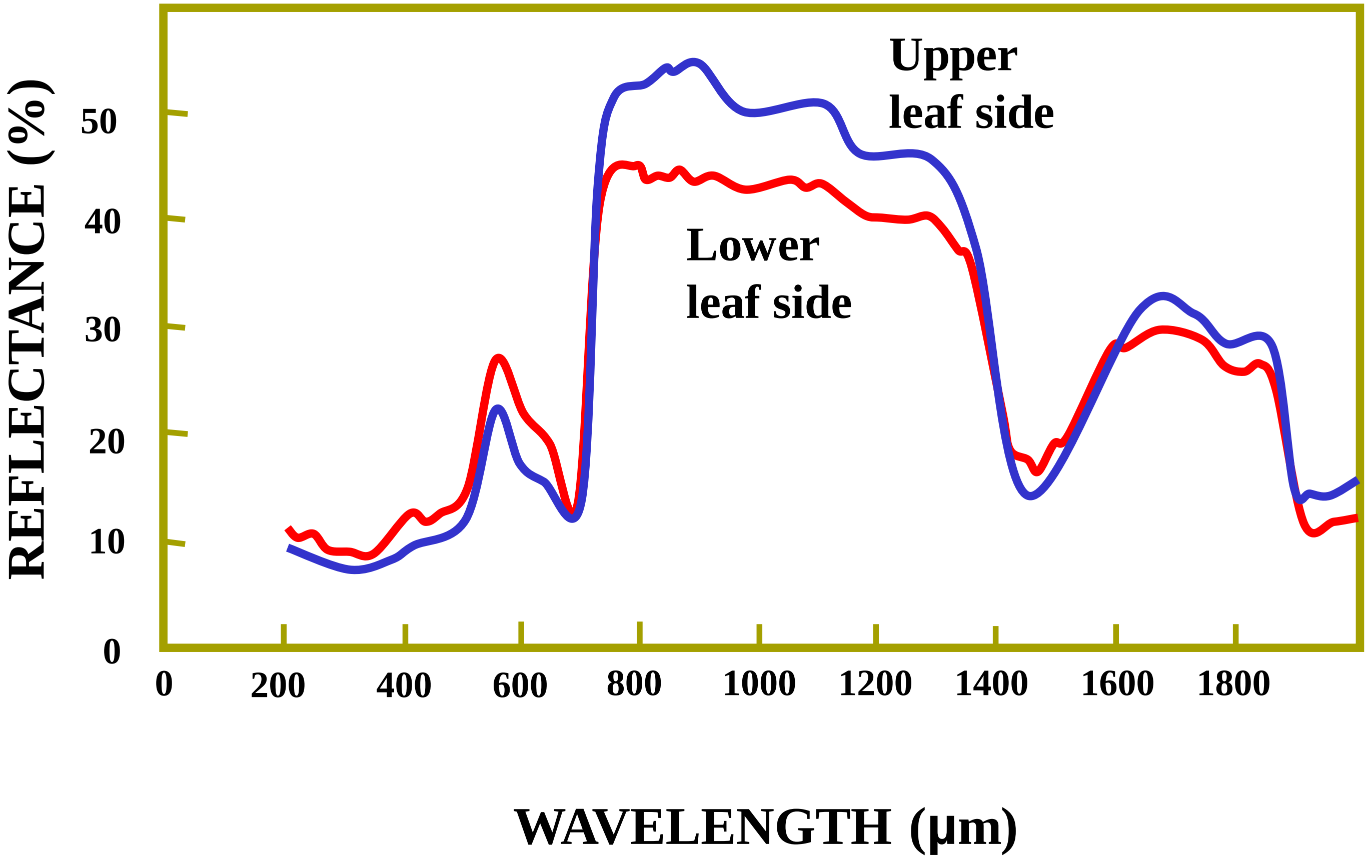
Spectral reflectance e.g. vegetation



Interactions with matter

four types :

phenomenon	example
absorption	blue water
scattering	blue sky, red sunset
reflection	coloured ink
refraction	dispersion by a prism

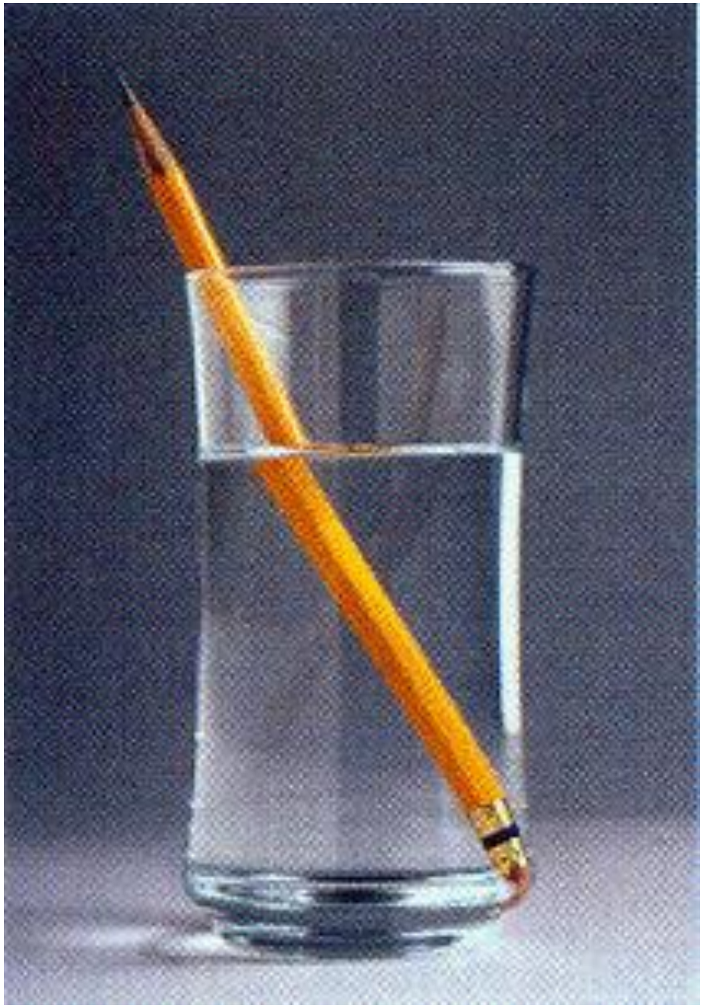
+ diffraction

Computer Vision

INTRO

perception
applications
light

Refraction



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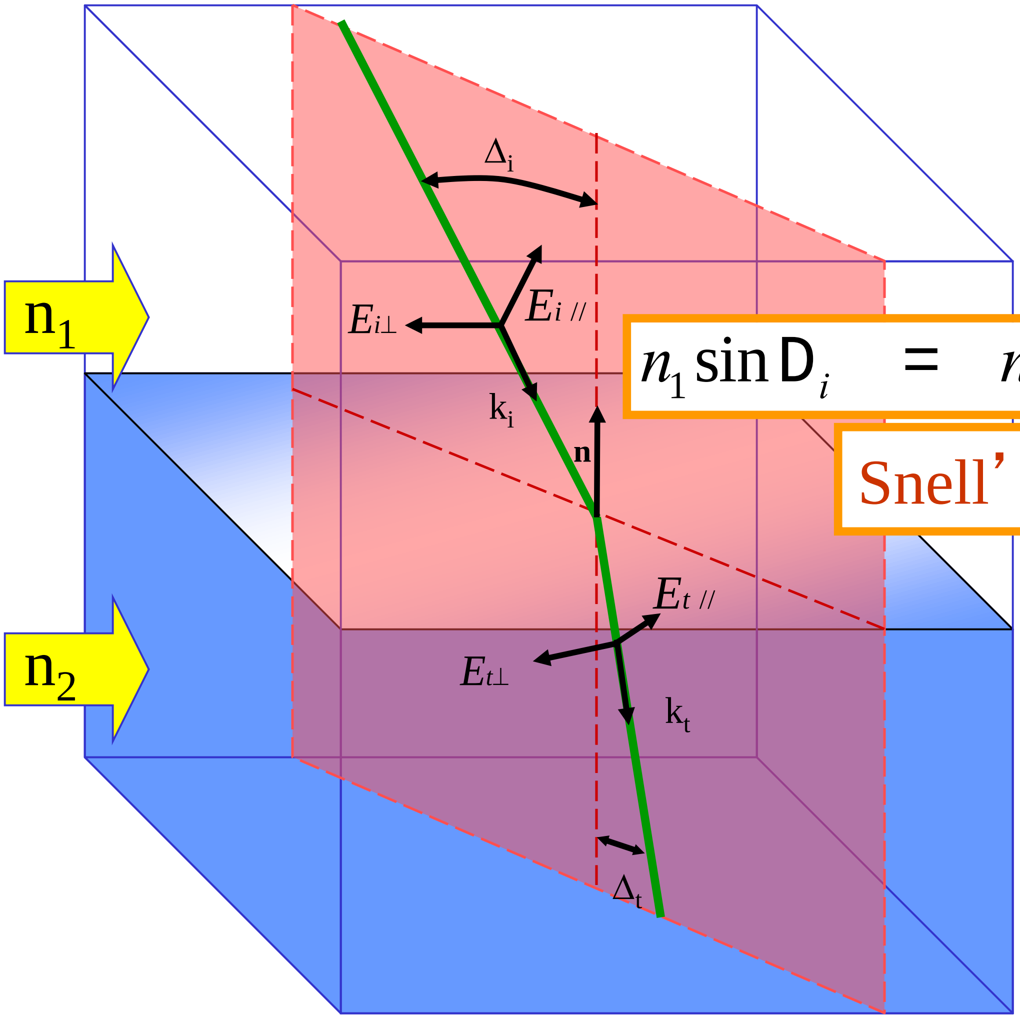
Refraction



$$n_1 \sin D_i = n_2 \sin D_t$$

Snell’s law

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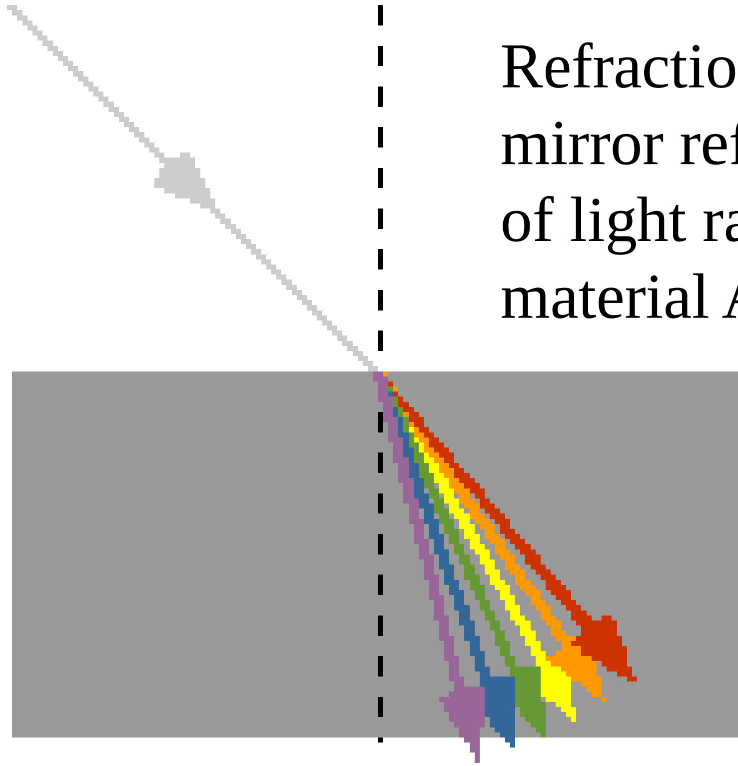
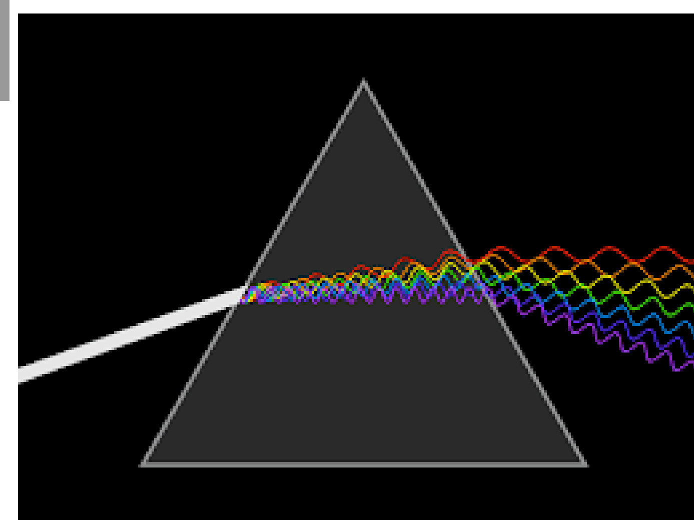
Dispersion



Refraction is more complicated than mirror reflection: the path orientation of light rays is changed depending on material AND wavelength !!!



Interactions with matter

four types :

phenomenon	example
absorption	blue water
scattering	blue sky, red sunset
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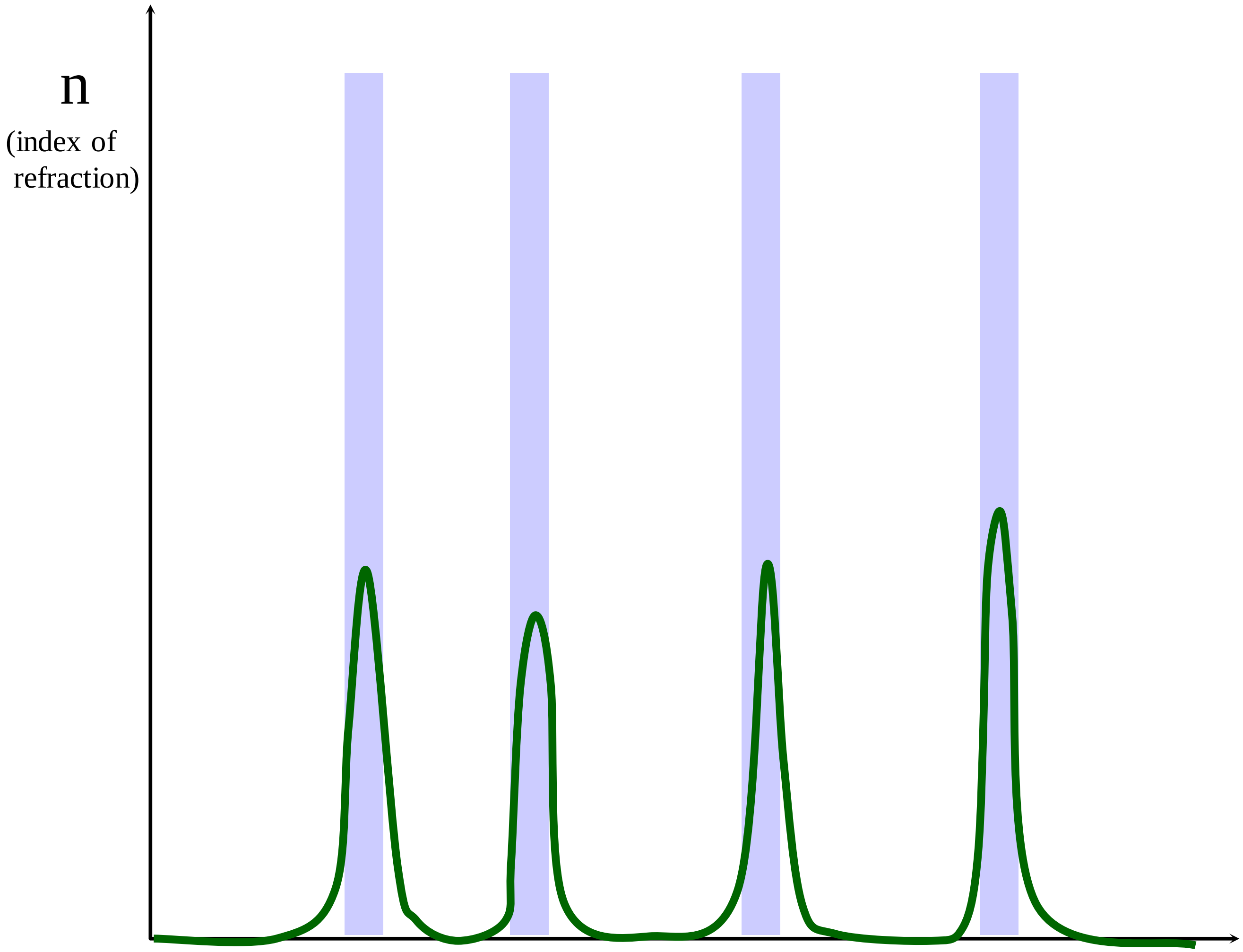
Absorption

Dissipation of wavelengths specific for the medium



Based on resonance frequencies of molecules -> peaks

Holes in sky light spectrum observed by Fraunhofer

The solar spectrum

Peaks around 500nm, hence human sensitivity for that part of the spectrum